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HIGHLIGHTS IN RESEARCH

Annual Report, 1960

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ROCKY MOUNTAIN STATION

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
OGDEN, UTAH
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Cover photo.—Facilities of the Northern Idaho Forest Genetics Center on the campus of University of Idaho at Moscow.

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PUBLICATIONS 45

(This report covers calendar year 1960 activities unless otherwise noted.)

FOREST MANAGEMENT RESEARCH

In evaluating the year's progress in forest management research, we find the major gain was receipt of an allotment that enables strengthening the station's program of research on lodgepole pine. A research center devoted to lodgepole pine studies was established this year at Bozeman, Montana, in cooperation with Montana State College. Before the end of 1961, this center will have two men devoting full time to this project. This gives us modest-sized projects in four timber types: ponderosa pine, western white pine, western larch, and lodgepole pine. We still lack programs in the Engelmann spruce and interior Douglas-fir types.

In a functionalized research organization such as ours, integration and coordination of research programs and research results between functional divisions are important and continuing responsibilities. During 1960 this division worked closely with personnel in Forest Economics Research in developing criteria and methods for collecting forest management information as part of inventory survey procedures, and in interpreting the resulting information. These two divisions also cooperated in evaluating timber cultural practices for specific areas under economic study. We believe these cooperative endeavors have substantial value in achieving coordination of work and in pointing up gaps in programs.

Study of research problems and delineations of these problems have been continued by all personnel throughout the year. This important and continuing task points toward the most efficient use of our resources to provide information for better management of forest lands.

As in past years, the following report on forest management research describes and discusses selected items of interest.

FOREST TREE IMPROVEMENT AND PLANTING

Heritability of Juvenile Height Growth in Western White Pine

In a forthcoming publication, Squillace, Bingham, and Robinson will discuss the nature of heritability, methods of its computation, and applications of heritability values to several improvement alternatives. They have estimated juvenile height growth heritability for western white pine by several methods. Using the most reliable method—analysis of variance components—they have estimated heritability at 15 percent. This estimate was based on fourth-year height growth of 4-year-old western white pine seedlings that had been outplanted in 1954 as 2-0 stock in plantations at Elk River and Fernwood in northern Idaho and at Randolph Creek in western Montana.

Heritability values indicate the genetic component of variation *only under conditions of the experiment*. Thus, the heritability estimates for a trait vary under different environmental circumstances and tree age even though the same computation method is used. If natural conditions do not approximate experimental conditions, we probably cannot expect as high a heritability nor realize as much improvement in the desired characteristic as was achieved in experiment.

Three outplantings were established several years ago at Emerald Creek and on the Priest River and Deception Creek Experimental Forests to study genetic and environmental components of variation under natural conditions. Seedlings now 10 years old were measured in detail for many characteristics for the first time in the fall of 1960. Although competing vegetation around each plant was removed in at least three of the six growing seasons since transplanting, the environment of these trees approximates the conditions planted seedlings face in nature. Estimates of heritability from these data will help direct and determine the emphasis and intensity of each phase of our western white pine improvement program.

Selective Fertilization in Western White Pine

If trees in a seed orchard are allowed to shed pollen naturally, there is danger of self-fertilization. Seedlings resulting from self-fertilization are undesirable because they usually grow more slowly than seedlings originating from cross fertilizations. Some western white pine individuals are highly self-fertile, but the majority of trees so far tested are moderately self-incompatible; a few are highly incompatible.

Highly self-incompatible trees are especially desirable in seed orchards.

One purpose of a recently completed study was to determine if any selective action is exerted to favor outcrossing when self and outcross pollens are competing. We tested the ability of four seed parents to discriminate for or against self pollen when in competition with outcross pollen from several trees. Two of these seed parents were self-fertile; the other two were moderately self-incompatible. Epicotyl height and relative germination time of self and outcross lots were used to determine the relative effectiveness of self and outcross pollen in producing germinable seed.

In the self-fertile trees, when self and outcross pollens were in competition neither self nor outcross pollen was more effective *per se*. We cannot expect, therefore, an abundance of outcross individuals due to some natural selective action. However, physiological differences between the two competing pollens may cause self pollen to be more effective in one instance but less effective in another.

In moderately self-incompatible trees, when self and outcross pollens were competing, the yield of selfed seed was low in comparison to the yield of outcross seed. Three out of four tests showed no significant difference ($P = < 0.05$) in epicotyl length between seedling lots resulting from pollination by (1) outcross pollen and (2) a mixture of 50 percent self and 50 percent outcross pollen. The fourth test showed significant difference in favor of outcross pollen. All four tests showed significant difference ($P = < 0.01$) in epicotyl length between selfed and outcross lots.

Albino seedlings in the ratio 1:3 were discovered in the selfed progenies of one moderately self-incompatible tree. Using this characteristic we could determine more accurately the amount of selfing when both self and outcross pollens competed. The following tabulation illustrates a selective action against self pollen:

Female parent	Male parent	Theoretical albino	Actual albino	Theoretical selfing	Actual selfing
Tree number	*Tree number*	*Percent*	*Percent*	*Percent*	*Percent*
64 X	64	25.0	25.3	100	100
64 X	[1](64+18)	12.5	5.7	50	23
64 X	(64+58)	12.5	4.3	50	17
64 X	[2](64+mm)	12.5	4.8	50	19

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[1] Pollen mix of 50 percent 64 pollen and 50 percent 18 pollen.

[2] Multimix of pollens from eight different trees.

Our studies of selective fertilization have led to several conclusions applicable to western white pine seed orchard management, provided that pollination is not done artificially.

1. All other things being equal, we should discriminate against self-fertile clones and favor highly self-incompatible clones when planning a seed orchard.
2. If self-fertile clones are included in the orchard, we cannot expect (except by chance) a mitigating effect against self-fertilization by some selective action.
3. For moderately self-incompatible clones in an orchard, we can expect outcross pollens to be more effective than self pollen in producing germinable seed. The degree of incompatibility probably indicates the relative magnitude of the effectiveness of outcross pollen vs. self pollen.

Stimulation of Male and Female Strobili Production in Western White Pine

Because abundant flowering is vital to production of seed in orchards and other production areas, we started a new experiment to test the effect of fertilizer (nitrogen and nitrogen-phosphorus-potassium) and release (20- by 20-foot and 30- by 30-foot spacing intervals) in stimulating male and female strobili production. Eighteen 1/10-acre sample plots were established in June 1960 in the Cathedral seed production area, Coeur d'Alene National Forest. Soil samples will be taken annually in each sample plot, and the strobili production evaluated for the various nutrient levels in the soil. The effect of fertilization and release on the number of sound and blind seed, seed weight, and germinability will be determined. Growth of sample trees in relation to thinning and fertilization is also being investigated. Future management of this area for seed production will be determined largely by the results of this experiment.

A related experiment to study the importance of time of fertilizer application has been established in a 34-year-old plantation in Coeur d'Alene National Forest near Haugan, Montana.

Germination of Spring-Sown Western Larch Seed Subjected to Pretreatment

A western larch spot seeding test was installed in the spring of 1960 on the Coram Experimental Forest. Equal lots of seed were pretreated as follows: (1) stratified for 30 days in moist sand at 38° F., (2) soaked in a U.S.P. 3-percent solution of hydrogen peroxide for 24 hours, and (3) a control (no pretreatment). After pretreatment was completed, half of each lot was repellent-coated with a formulation of endrin-arasan.

Laboratory tests showed this seed to be 45-percent viable. Nearly all the viable seed germinated when stratified and then sown at a favorable time in the spring, but the untreated and peroxide-treated seed had much less germination than the seed that was only stratified. Germination was not significantly different between (1) repellent-coated and uncoated seeds, (2) screened and unscreened seed spots, (3) hydrogen peroxide pretreated and control seeds, and (4) aspects. Significantly more seed germinated from (1) the late sowing than the early sowing, and (2) stratification pretreatment than hydrogen peroxide treatment.

Delayed germination will be followed in 1961 in order to evaluate the whole course of germination completely.

Ten-Year Results of Spot Seeding Lodgepole Pine

Natural reproduction failures are rare following clear cutting of lodgepole pine in central Montana. However, on cuttings that have been accidentally and heavily burned the seed supply can be lost and failures can occur. A test on the Lewis and Clark National Forest demonstrates that lodgepole pine can be successfully spot seeded on such areas when rodents are absent and weather conditions during the early growing season are favorable.

Ten-year-old lodgepole pine plantation established by spot seeding. Lewis and Clark National Forest, Montana.

The experimental area was prepoisoned with thallium-coated sunflower seed. Seeds were planted in scalped spots, and half of the spots in the test were covered with conical wire screens during the first growing season.

Stocking values for a 10-year period are shown in the table at the top of page 4.

Stocking of both screened and unscreened seedspots stabilized after the fifth year. The distribution and number of stocked spots per acre were adequate after 10 years.

Planting Ponderosa Pine Following Aerial Spraying of Brushfields

A major problem in planting ponderosa pine in the Intermountain region is planting slopes too steep to be worked by machines. Gentle slopes can be planted successfully by machine in previously plowed furrows. On steep slopes, however, no method of hand site preparation has proved consistently successful. The station has been cooperating with Region 4 in attempting to find a successful method of preparing steep slopes for hand planting. Aerial spraying with herbicides is one method tested.

Date of examination	Screened			Nonscreened		
	Stocked spots[1] per acre	Seedlings per stocked spot	Stocked spots	Stocked spots[1] per acre	Seedlings per stocked spot	Stocked spots
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
7/23/1950	744	3.2	82	654	2.9	72
9/14/1950	763	3.7	84	672	3.0	74
6/13/1951	717	3.4	79	617	2.6	68
8/13/1951	699	3.3	77	608	2.5	67
6/ 7/1955	645	2.8	71	526	2.2	58
9/29/1959	626	2.8	69	526	2.2	58

[1] One or more live seedlings per spot.

Forty acres of brushfield on the Boise Basin Experimental Forest were sprayed by helicopter with 2,4,5-T, 2,4-D, and Dowpon in four mixtures each on 10-acre plots. The plots were first sprayed in the summer of 1958 and were resprayed in 1959. We hoped that spraying would eliminate competing vegetation sufficiently to permit hand planting without further site preparation. In the spring of 1960, the four sprayed plots and one unsprayed plot were divided. Half of each plot was planted by hand without further preparation; the other half was planted by a machine in previously plowed furrows. Both east and west aspects were represented on each plot.

Three types of planting stock were tested on these sprayed plots. Regular 2-1 nursery stock was planted on all the machine-planted portion and most of the hand-planted portion of each plot. However, three sample plots were installed on each aspect of each sprayed plot in the hand-planted portion. On these sample plots we tested regular 2-1 stock, 2-1 stock with a fertilizer pellet added to each planting hole, and 2-year-old seedlings in tar paper containers 12 inches long.

Results of survival counts in the fall of 1960 showed that aerial spraying alone was not adequate site preparation for successful planting. This fact is emphasized in the following tabulation showing first growing season survival of machine-planted stock and three types of hand-planted stock. Survival of trees planted by machine in plowed furrows was 88 percent compared to an average of 28 percent for all types of stock planted by hand without the furrows.

Aspect	Machine planted	Hand planted types of stock			
		2-1 Stock regular	2-1 Stock fertilized	Tar paper containers	All types
		Percent			
East	90	48	29	43	40
West	86	16	16	16	16
Average	88	32	23	30	28

Aspect affected survival on plots planted without furrows. On these plots, survival on west aspects was less than half that on east aspects. Furrowing practically eliminated the effect of aspect.

The three types of stock tested were nearly equal except that survival of the fertilized trees was lower than that of other types on east aspects.

Differences between spray treatments were somewhat obscured by the second application; it increased the effectiveness of the lighter formulations. The important finding is that none of the spray treatments were adequate without additional site preparation.

We shall continue search for an economical and efficient method of site preparation for planting steep slopes. A satisfactory solution to this problem is important to the forest management program of the region.

SILVICULTURE

Ponderosa Pine Regeneration on Scarified Group Clear Cuttings

For the past 3 years we have been testing scarification as an aid to natural regeneration of ponderosa pine in central Idaho. Thirty-one small clear-cut openings on the Boise Basin Experimental Forest were thoroughly scarified prior to seedfall from the bumper cone crop in 1958. Satisfactory coverage of these areas by seed was confirmed by use of seed traps. Last year we reported on measurements of germination, mortality, and survival of seedlings through the first year.

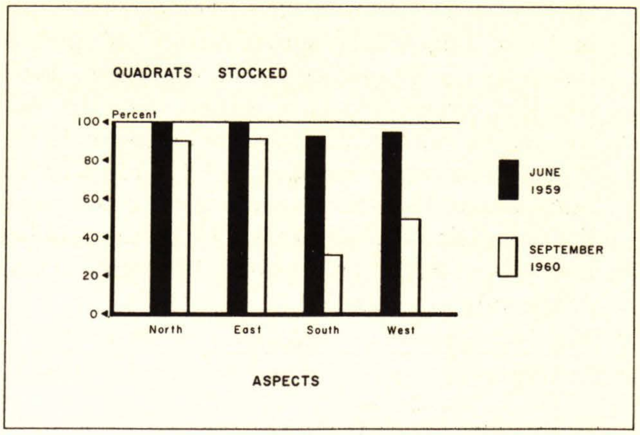
First-year measurements revealed that both initial germination and first-year mortality were highly variable. At the end of the first growing season the numbers of surviving seedlings ranged from 50 to 206,000 per acre.

Number of seedlings per acre, though valuable, is not the best measure of reproduction because it does not show the distribution of seedlings. A better measure is quadrat stocking, a term that expresses the percentage of small plots or quadrats containing at least one seedling. In this study, quadrat stocking was measured on transects or lines of milacre quadrats crossing the scarified openings from side to side and passing near the center. Periodic seedling counts on these transects show the changes in stocking through two growing seasons.

The most obvious differences between scarified openings were related to aspect. The effect of aspect on mortality and survival is shown in the following graph of quadrat stocking in the spring of 1959 and the fall of 1960.

Initial stocking was high on all aspects, ranging from 89 to 100 percent. Two growing seasons later, stocking was obviously higher on north and east aspects than on south and west aspects.

A common standard for minimum acceptable stocking is 40 percent of milacre quadrats stocked. Based on this standard, plots on south, southeast, and southwest aspects averaged less than acceptable stocking after 2 years. Plots on north, east, northeast, and northwest aspects were well above the minimum stocking standard after two growing seasons. Summer mortality, mostly from drought and insolation, was largely responsible for the differences in stocking after 2 years. Southerly aspects suffered greater mortality from drought and insolation because of higher surface temperatures and longer exposures to high temperatures on south slopes.



We conclude from this and other tests that natural regeneration is unreliable on southerly aspects in central Idaho.

Engelmann Spruce Regeneration

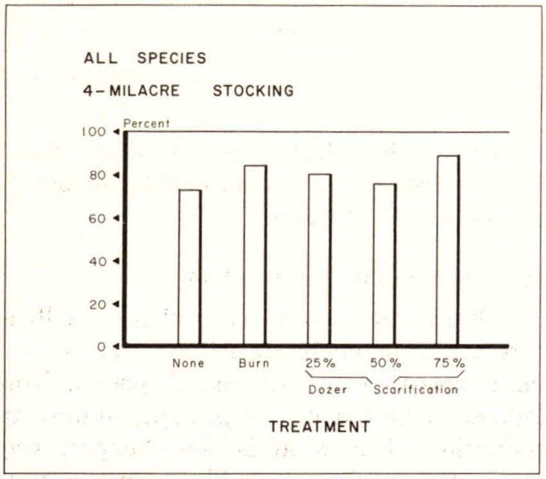
Much has been written about seedbed requirements for adequate regeneration of Engelmann spruce and its associated species. Mineral seedbed is necessary for prompt, abundant reproduction. But what is the cheapest way to create this condition? Will prescribed burning suffice, or should mechanical scarification be used? If scarification is better, then what degree of area coverage will create conditions for optimum stocking?

Getting answers to these questions is the objective of a cooperative study started on the St. Joe National Forest in northern Idaho in 1954. Helping in the study were the St. Joe National Forest, Potlatch Forests, Inc., the University of Idaho, and Intermountain Station. Five-year results on the progress of regeneration are now available.

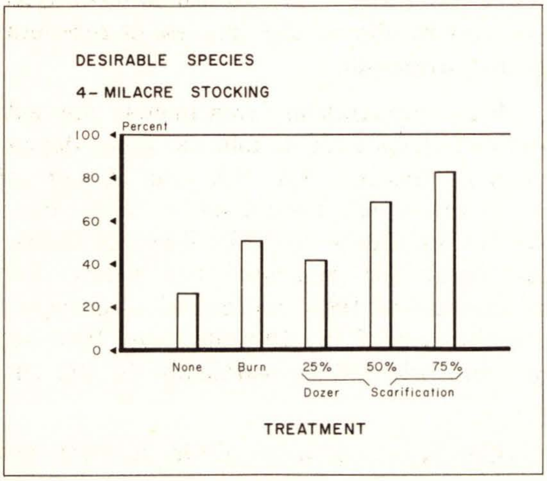
Site preparation treatments applied to clear-cut strips were as follows: three degrees of dozer scarification (25, 50, and 75 percent of the area covered), prescribed broadcast burning, and an untreated control. Each of these five treatments was replicated two times. During the summer of 1960, reproduction surveys were made in each of the 10 plots using two random transects oriented perpendicular to the cutting line.

Our interest is primarily in the three or four species that have best commercial potential.

Burning increased 4-milacre stocking of "desirable" species (western larch, Douglas-fir, grand fir, and Engelmann spruce) from 26 percent (control) to 50 percent. On the three dozer-scarified areas, stocking varied directly with the degree of scarification—from a low of 41 percent (25-percent coverage) to 82 percent on the plots where 75 percent of the ground was scarified. Satisfactory stocking (65 percent or better) was obtained only when 50 percent or more of the area was scarified.



Balancing the costs of these various treatments against the stocking achieved shows an advantage for dozer scarification over prescribed burning. For prompt regeneration on favorable northerly exposures, dozer scarification to cover 50 percent or more of the area seems to be the most promising technique. If a sale area is too steep for this type of site preparation, prescribed burning is far superior to no treatment at all.



Crown Thinning in Western Larch

In cooperation with the Lolo National Forest in Montana we tested crown thinning in a 50-year-old, even-aged larch stand in October 1949. We selected the stand, growing on a medium-quality site, because it showed a distinct depression in growth beginning about 25 years earlier. Thinning was accomplished by selecting 150 to 200 crop trees per acre and using two rules of thumb in thinning: (1) the "D + 4" rule, and (2) the "3′ to 6′ crown" rule. In the former method, all trees were removed around each crop tree in a circle whose radius in feet was equal to the diameter of the tree in inches, plus 4; all stems smaller than 5 inches were cut with an ax, and the larger ones were poisoned or girdled. In the second method, trees were removed by cutting and poisoning or girdling within a 3- to 6-foot radius on at least three sides of the crown of each crop tree. Crop trees were selected chiefly from dominant and codominant trees that had good form and were spaced about 15 feet apart. Larch was the predominant species, but a few lodgepole pine, Douglas-fir, and ponderosa pine were also given preference in crop tree selection in that order.

Cost ranged from 1.9 man-days per acre for the "3′ to 6′ crown" thinning to 2.5 man-days for the "D + 4" thinning. These costs probably can be reduced by use of more efficient tree removal methods including mechanized bow saws.

The study led to the following conclusions:

1. Growth in overstocked western larch stands can be transferred to selected crop trees through thinning.
2. Growth response to thinning is related to the degree of overstocking. This emphasizes the importance of thinning stands before overstocking becomes too severe.
3. Growth response is also related to stand structure. The larger dominant and codominant trees of good vigor show the best response. They are better able to respond to increased growing space because of larger crowns and better developed root systems. This illustrates the importance of selecting the best trees as crop trees.

4. These thinnings probably are heavy enough to insure good growth until commercial cuttings are possible in the stand. However, we must wait to determine whether the competition from other than crop trees and other vegetation will develop and consequently slow diameter growth on the crop trees.
5. The heavier thinning resulting from the "D + 4" rule appears to result in greater diameter, basal area, and volume growth than the lighter "3′ to 6′ crown" rule.

GROWTH AND YIELD

Soil and Stand Factors Related to Height Growth of Lodgepole Pine

Tree height is a stand factor of great importance in forest management. It is not only a major variable that determines tree volume, but is the most commonly used measure of forest site quality in this country.

An intensive study[1] of soil and stand factors in the lodgepole pine type has enabled us to define more accurately the specific variables having greatest influence on height growth of this species. The height of dominant lodgepole pines in Montana was found to be highly correlated with relatively few basic factors. The relation of dominant height to these factors is expressed by the following equation:

$$Y = 1.605571 - 0.000022X_1 + 0.041494X_2 - 0.500059X_3 + 0.001038X_4 + 0.303679X_5 + 0.002262X_6 + 0.037978X_7$$

Where Y = logarithm of average dominant height

X_1 = stems per acre

X_2 = average diameter of dominant trees

X_3 = average crown length ratio of dominant trees

X_4 = average percentage available moisture in the effective soil profile

X_5 = average percentage nitrogen in the effective soil profile

X_6 = average exchangeable phosphorous in the effective B horizons

X_7 = reciprocal of age X effective profile depth

This equation explained 91 percent of the variation in dominant height.

A simpler equation for more general use, which explained 88 percent of the variation in dominant height, is:

$$Y = 1.713976 - 0.000024X_1 + 0.040888X_2 - 0.508412X_3 + 0.047573X_7$$

The independent variables are the same as for comparable expressions in the first equation.

Cooperative Study of Grand Fir Specific Gravity

Grand fir, one of the northern Rocky Mountains' better pulping species, is being studied to estimate attainable growth rates and yields. In order to express these yields in terms of pounds of fiber per acre, the variation in specific gravity of grand fir was measured throughout the forests of northern Idaho during the summer of 1960. Potlatch Forests, Inc. and Inland Empire Paper Company provided valuable assistance in the field work, and the wood samples were dried in Long Lake Lumber Company's kiln. The resulting information will be analyzed in the form of tree "weight" tables analogous to the tree volume tables currently used in timber cruising.

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[1] In cooperation with the Montana State University School of Forestry.

FOREST DISEASE RESEARCH

◀ Rust resistant tree No. 19 at Crystal Creek, St. Joe National Forest. Bags cover cones control pollinated the previous year; they prevent loss of cones to insects and squirrels.

In 1960 the station was assigned entire responsibility of research in the white pine blister rust resistance project, and all facilities at the Northern Idaho Forest Genetics Center at Moscow, Idaho, are now a part of the station. Previously the station had been a cooperator in this project with National Forest Administration and the University of Idaho.

Since 1923 the management of western white pine in the Inland Empire region has been faced by a tremendous obstacle, blister rust. Now, the 35-year-long war against this introduced parasite is turning in our favor. Two decisive breakthroughs—immediate, direct control of the rust disease by antibiotics,[2] and future assurance of long-range, less expensive control by using inherently rust resistant planting stock[3] —have turned the tide in this seemingly endless and often discouraging battle.

The two new control methods supplement each other admirably. Control by antibiotics is relatively economical, in terms of past costs of ribes eradication, even though it will continue to constitute a large portion of white pine management costs. Thus immediate problems in economical management of white pine stands under the handicap of blister rust[4] are approaching solution. There is great promise that temporary immunization of the pine host through periodic application of antibiotics will assure a raw material supply for the western white pine industry for many years to come. Meanwhile, we are proceeding as rapidly as possible toward the less expensive but long-range objective—mass production of inherently resistant planting stock.

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[2] See Moss, Virgil D., Henry J. Viche, and William Klomparens. 1960. Antibiotic treatment of western white pine infected with blister rust. Jour. Forestry 58: 691-695.

[3] See Bingham, R. T., A. E. Squillace, and J. W. Wright complete citation in Publications section of this report.

[4] See Matthews, Donald N., and S. Blair Hutchison. 1948. Development of a blister rust control policy for the national forests in the Inland Empire. U. S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Station Paper 16. 116 pp.

Part of the 40-acre breeding arboretum near Moscow, Idaho. Trees planted here have successfully resisted infection from three intensive artificial inoculation attempts with blister rust spores.

Direct control by antibiotics cannot be supplanted for perhaps 25 years, but resistant planting materials are now only a matter of time.

LONG-RANGE RUST RESISTANCE BREEDING PROJECT

Resistance of the better first-generation (F_1) progenies from controlled crosses among apparently resistant field selections has been gratifying. The average of the better F_1 progenies contain 30 percent seedlings that survive repeated heavy exposures to the rust disease. Furthermore, resistance genes from certain of the wild parents are clearly "additive" in effect, so that their accumulation toward the production of increasingly resistant progenies with each successive generation of selection and breeding is measurable.

From heritability and genetic gain analyses we can predict a level of survival for F_2 progenies of near 50 percent, *i.e.* 20 percent greater than in F_1 materials. This level of survival under intense rust exposure will meet practical planting objectives. Since less than 10 more years of experimental crossing of selected F_1 seedlings and testing of resultant F_2 progenies will be required to verify the predicted 20-percent gain, the years 1970 to 1975 may see large-scale establishment of seed orchards to mass produce the seed of resistant trees.

One hundred acres of seed orchards, ultimately providing seed for planting 10,000 acres annually, could be in partial production as soon as 1985 to 1990. Depending on ability to produce and test F_2 materials, these orchards might produce either (1) F_2 seed having about 50-percent rust-survival value, produced from natural crossing among grafts from selected F_1 seedlings, or (2) F_3 seed with possibly 65- to 70-percent rust-survival value, produced from natural crossing among selected F_2 seedlings.

Sandpoint Seed Orchard

The Sandpoint, Idaho, Experimental Seed Orchard, a cooperative project with Region 1 and the Kaniksu National Forest, comprising some 17 acres and 1,600 grafted trees from selected rust-resistant parents, was established in early spring 1960. Establishment of this seed orchard brings the dream of mass production of seed from rust-resistant trees closer to realization. This orchard will serve the further useful purpose of a laboratory for testing techniques of seed orchard operation.

Establishment of the Sandpoint orchard followed more than 3 years of grafting and site preparation. Survival in the orchard of grafted plants through the fall of 1960 was excellent—92 percent—and attests the careful and contin-

Experimental seed orchard at Sandpoint, Idaho. This 17-acre area, planted in the spring of 1960, includes nearly 1,600 grafted trees with scions from 13 different parent western white pine trees with known ability to transmit rust resistance.

uing care by Kaniksu National Forest personnel. Induction of sterility and inhibition of pollen production by application of a "gametocide" (FW-450, a, B-dichloroisobutyrate) is being investigated as a possible means of controlling pollination within seed orchards. Exploratory tests, while inconclusive on white pine, showed that pollen from aspen catkins treated prior to pollen meiosis was ineffective, and no seed set resulted when it was used to pollinate normal female flowers.

New Sources of Resistance

Selection and testing of up to 400 wild parents continues; latest test-crossing methods permit checking of about 50 new trees per year. About 230 wild candidates have been found, and about 150 of these are already tested or are under test.

In searching for new sources of resistance, especially for resistance to more than one physiologic race of the rust organism, we have commenced a program of interspecies hybridization involving these Eurasian white pines: Armand pine, Swiss stone pine and its Siberian variety, Korean pine, Japanese white pine, Balkan pine, and Himalayan white pine. Special care has been given to obtaining pollens and seed from relatively cold-resistant native stands of good growth and form. Cooperators in Bulgaria, Czechoslovakia, Finland, Germany, Greece, Hungary, India, Korea, Japan, and Yugoslavia, supplied more than 30 fresh pollens; these were received and used in the spring of 1960 in attempting to produce some 25 interspecies hybrids. Results will not be known for several years.

Nature of Resistance

Finding the factors responsible for disease resistance in plants has been one of the most difficult problems facing biologists for many years. Blister rust resistant western white pine selections and their progeny at or near the Northern Idaho Forest Genetics Center offer unique advantages for studying the rust-resistance mechanism in this species. Research now under way will give us much-needed information about the biochemistry of white pine, particularly in relation to resistance and susceptibility to infection by the blister rust fungus.

Needle and bark tissues from resistant and susceptible parents and progenies are being analyzed to determine presence of several groups of chemical compounds, especially the sugars, amino acids, organic acids, phenols, and pigments. Dry matter content and pH of the tissues are also being studied.

Resistance Through Induced Mutations

The recently successful application of chemical mutagenic agents to certain commercial field crops suggests their possible use with forest tree seed. Diethyl-sulfate and ethyl-methane-sulfonate have produced high mutation frequencies with few chromosomal aberrations. In contrast to radiation treatments, use of these chemicals also results in high survival relative to degree of mutagenesis. Since pine seed is quite radiosensitive, these mutagenic agents may effectively induce useful mutants in the pine.

A preliminary screening test on pine seed resistant to blister rust has been established; it uses ethyl-methane-sulfonate at varying concentrations and soaking times. Surviving seedlings are being observed for gross mutations and will be tested for possible induced resistance to blister rust infection.

WHITE PINE POLE BLIGHT

Moisture Stress Seedling Study

Seedling beds installed in 1956 to determine the effects of imposed moisture deficiency on root and top development of seedlings of western white pine and some associated tree species in relation to pole blight disease were dismantled. This study resulted from findings by Leaphart and Copeland[5] of a relationship between the rootlet condition of white pine pole stands affected by pole blight and two soil characteristics, namely, effective soil depth and available moisture-holding capacity.

Moisture stresses had been imposed during the 1958, 1959, and most of the 1960 growing season. Seedlings were grown in rocky soil, hardpan, and good soil for the entire 5-year period. Detailed data on root and top development of each seedling were taken, but results await analyses.

DWARFMISTLETOES

A problem analysis on dwarfmistletoe covering research and survey needs in a program to control the dwarfmistletoes of Douglas-fir, lodgepole pine, and western larch in the Intermountain and Northern Rocky Mountain regions was completed during 1960. This analysis lists and describes the major problems, lists information needed to solve these problems, and suggests some 30 individual studies needed to provide the necessary information.

Development and Growth Impact in Western Larch

Western larch trees infected with dwarfmistletoe were selected for study in eight permanent sample plots that were established in a thinned immature stand of larch in the St. Regis District, Coeur d'Alene National Forest. The 256 study trees were identified, measured, and described. Development of dwarfmistletoe and growth of the stand under four thinning intensities will be closely observed, and spread and intensification of the parasite under four thinning intensities will be measured. Growth of trees having different degrees of infection (free, light, medium, and heavy) will be compared within thinning treatments. The trees will be reexamined in 1962 and at 5-year intervals thereafter.

Selected trees in this thinned stand of western larch poles will be studied to determine the spread, intensification, and growth impact effects of dwarfmistletoe.

Spread and Intensification in New Lodgepole Pine Stands

This year data were taken on 27 new plots to determine the spread and intensification of the lodgepole pine dwarfmistletoe. These data included measurements taken from infected border stands into the new reproduction in clear-cut blocks. Infected tree samples were collected to measure the minimum age-susceptibility of lodgepole seedling-sapling-sized trees. Our data are being combined with information from a similar study at the Rocky Mountain Forest and Range Experiment Station. Analysis should provide some definite recommendations on the length of time residual lodgepole pine stands can be left before they should be cut to prevent infection or keep it to a minimum in newly regenerated cutting areas.

ROOT DISEASE

The dying of eastern white pine in two 50-year-old plantations near Sylvanite Ranger Station, Kootenai National Forest, is caused by the root stain fungus *Verticicladiella* sp. This fungus invades the root system and stains the sapwood a dark chocolate color. The stain progresses up the roots, past the root collar, and for a short distance up the main stem. Tree mortality is quite rapid; it occurs soon after leader growth reduction and crown discoloration, and is caused by girdling at or near the root collar.

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[5] Leaphart, Charles D., and Otis L. Copeland, Jr. 1957. Root and soil relationships associated with the pole blight disease of western white pine. Soil Sci. Soc. Amer. Proc. 21: 551-554.

This disease, which radiates from a common center, may completely destroy the two plantations. Although it has killed eastern white pine, it has not yet killed trees of native species growing in the diseased centers. The fungus was found in one lodgepole pine root, but no evidence of similar infections in other native species has been observed.

WHITE PINE BLISTER RUST MICROCLIMATE

Dew Supplies Sufficient Moisture for Rust

Saturated air that deposits free water on the leaves of ribes shrubs is considered necessary for germination of the various spore stages of white pine blister rust. Lack of moisture may well be a factor limiting development of rust on ribes in the Inland Empire area during summer. Local intensification of rust on ribes has been observed along the bottoms of many moist canyons in the white pine belt where heavy dew occurs.

Does dew alone provide sufficient moisture on the under surface of ribes leaves in the Inland Empire area for germination of blister rust spores?

To answer this question, potted ribes were inoculated and exposed only to dew during June and July in a meadow near Benton Creek on Priest River Experimental Forest, Idaho. Moderate to heavy infection developed. By mid-July, teliospores had been produced and sporidia discharged, and heavy rust intensification almost completely defoliated the test plants. Subsequent new leaves became infected. This study amply demonstrated that the dew which develops along valley bottoms in the Inland Empire provides enough moisture to germinate the various spore stages of the rust.

ANTIBIOTIC CONTROL OF FOREST DISEASES

All the numerous tests of disease control by various antibiotic materials and concentrations started in 1959 (see 1959 Annual Report, p. 13) were still inconclusive in 1960. However, one disease, the Rhabdocline needle cast of Douglas-fir, appeared to be susceptible to control by antibiotic materials.

No infected foliage was found in June 1960 on some young Douglas-fir trees that had been infected in June 1959 before the semicarbazone derivative of cycloheximide (Acti-dione) had been aerially applied. However, trees already infected in 1959 that were not sprayed, or were sprayed with other antibiotic materials, still supported considerable infected foliage in 1960. These studies are being continued.

FOREST DISEASE SURVEYS

Detection Surveys

St. Joe and Clearwater National Forests.—Dwarfmistletoe detection surveys, restricted to a roadside surveillance, were completed this year in the St. Joe and Clearwater National Forests. Detailed surveys were not needed because (1) observations indicated the dwarfmistletoe problem to be less severe in these two forests than in any other forested area in Region 1 (except possibly the interior of the Flathead Forest), and (2) the station's forest survey crews and the region's timber inventory crews are recording presence or absence of dwarfmistletoe on all plots they establish.

The roadside surveillance and inventory plot records that have been analyzed to date confirm the suspected low frequency of dwarfmistletoe occurrence. The only portion of these forests where the parasite is commonly found is the western one-third of the St. Joe National Forest, where infection was found in Douglas-fir, western larch, and lodgepole pine. Occasional centers of infection in western larch and lodgepole pine were found throughout both forests.

General.—Damage from needle diseases varied in Region 1 in 1960 according to host and causal organism. The larch and lodgepole pine needle diseases were present, but most infected areas were only lightly attacked. White pine needle diseases were less serious than in 1959. The Douglas-fir needle blight, *Rhabdocline pseudotsugae*, was still present in epidemic intensity. The ponderosa pine needle blight, *Elytroderma deformans*, was about as prevalent as it has been in each of the last few years. One seriously damaged stand on the Colville National Forest was marked for cutting to salvage damaged trees before heavy mortality occurs.

A stand of limber pine infected with the dwarfmistletoe *Arceuthobium cyanocarpum* was found in eastern Montana near Red Lodge, Custer National Forest.

Ponderosa pine was seriously defoliated in three locations in Montana following a severe freeze in November 1959, before the trees had winter hardened. No permanent injury resulted as only a few terminal and lateral buds were killed.

A severe frost occurred the morning of June 21 over much of the station territory from Great Salt Lake to northern Idaho. Much new growth on Douglas-fir was killed back in many locations at lower elevations. Damage was especially heavy on the Cache National Forest. Similar but less serious damage occurred on Engelmann spruce and grand fir on the St. Joe National Forest. New growth in rust brooms (yellow witches'-broom) on subalpine fir was severely damaged by this frost on the Cache, Caribou, and Sawtooth National Forests. This damage made it impossible to judge results of our 1959 and 1960 antibiotic tests on this rust fungus.

Post-Control Biological Evaluation Survey

Dwarfmistletoe control was undertaken by forest personnel in lodgepole pine sale areas in 1959. This control work was to reduce dwarfmistletoe to an innocuous level in the clear-cut blocks by removing residual diseased trees. Two areas were in the Lewis and Clark and one in the Deerlodge National Forest. Sale areas had been cut between 1948 and 1952 by the clear-cut block system. All blocks contain new reproduction from 4 to 12 years old.

In 1960, we surveyed the treated areas to determine effectiveness of the control operation (from the biological standpoint) in eliminating infection. In the three cutting areas, 33 treated clear-cut blocks totaling about 1,200 acres were surveyed. Some infection was found in 16 of the blocks, and an appreciable amount was found in 9 of these. Although we do not know definitely how much dwarfmistletoe infection can be tolerated, it appears that 9 of these 33 blocks should be reworked.

Results from partial analysis of data indicate that dwarfmistletoe control operations in lodgepole pine clear-cut blocks can be effective if certain precautions are taken. It appears that some infections were missed because of:

1. Poor visibility. Some blocks that contained numerous missed infections were worked when weather was too bad.
2. Incomplete control on coverage. Some small strips or pockets were not covered by eradication crews.
3. Inadequate training of crew members. No one can identify dwarfmistletoe-infected trees with 100-percent accuracy. Therefore, the best training available for eradication crews in the recognition of infected trees is essential to successful control. Eradication crews should be instructed by a competent pathologist unless a forest is adequately staffed to carry out this biological phase of the operation.

FOREST INSECT RESEARCH

The program of research and insect surveys continued as planned at Intermountain Station during 1960. We attempted to balance our research so as to include detailed studies on several insect species of primary importance, to investigate techniques that might be generally applicable to all forest insect problems, to use all opportunities to evaluate possibilities of biological control, and to translate research results into practical use cooperatively with forest managers.

Selected examples from this year's program illustrate the nature of our approach: research on Douglas-fir beetle, improvement in sampling techniques, use of biological agents in control, and a cooperative pilot plant test with Region 4 against tussock moth.

Insect surveys revealed that high-level populations of several serious pests continue to cause problems for land managers throughout the station work territory.

INSECT STUDIES

Douglas-fir Beetle

Three phases of a long-term study of the epidemiology of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., are reported. These are: (1) a test of a 1/10-square-foot arch punch for sampling populations, (2) a test of 2-percent DDT spray for preventing infestation of green logs by this beetle, and (3) a test of methods of attracting beetles as a means to develop a practical trap tree procedure for control. As work progresses, we are accumulating data on many factors that singly or together change the relative abundance of this beetle.

Sampling methods.—Sound sampling methods are essential in these studies and improvements are constantly being sought. The 6- by 12-inch sampling unit used previously had some undesirable characteristics. Boundaries of samples had to be measured; exact cutting offered difficulties; and actual size of samples varied in spite of care exercised in obtaining the bark sections. In order to develop a better method, a 1/10-square-foot circular bark punch was designed and tested. This punch produced better working material than cutting 6- by 12-inch rectangular samples, especially where bark was less than 1/2-inch thick. Besides being faster in use and more accurate in area, this punch permitted more samples to be taken in equal lengths of time. Less fatigue and error in counting brood on the smaller punch samples were additional advantages. Paired samples of each size were collected and counts made on number of Douglas-fir beetle entrance holes and length of egg galleries. The comparison follows:

	6-by 12-inch samples	1/10-sq. ft. samples
Entrance holes (average per sq. ft.)	7.9	7.4
Samples needed for equal accuracy[1]	256	330
Length of egg galleries (inches)	48.2	45.0
Samples needed for equal accuracy[1]	163	211

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[1] For 10-percent error at 95-percent level of probability.

Average counts on 1/10-square-foot samples were slightly lower than those on 6- by 12-inch samples, and 1.3 times as many bark punch samples were needed to obtain a given accuracy of estimate. However, because nearly three times as many bark punch samples could be taken in equal time, the 1/10-square-foot unit still had an advantage over the 6- by 12-inch sampling unit in this particular test. This opens up possibilities of testing arch punch samples in comparison with rectangular samples of different sizes with several species of bark beetles.

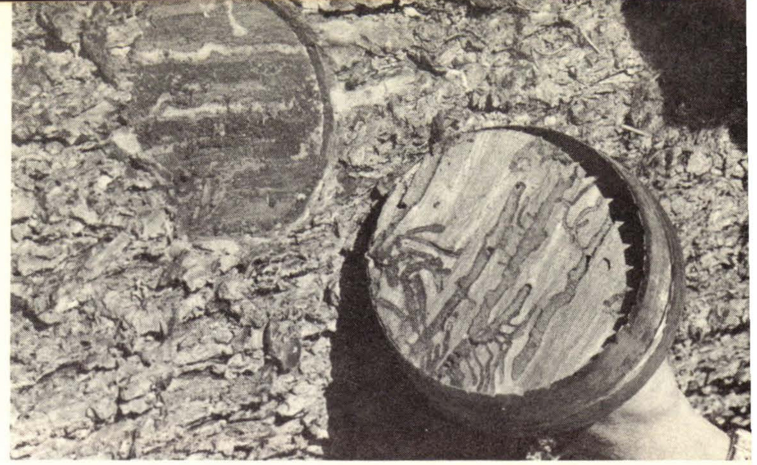
DDT Protects Green Logs.—In 1959, a 2-percent DDT emulsion spray was tested to determine whether it could prevent infestation of green logs by Douglas-fir beetle. Applications reduced the number of egg galleries but did not affect the number of live brood established. This year we studied the effect of a second treatment and tested the possible repellancy of the petroleum solvent in the spray concentrate. It had appeared in early tests that repellancy by the solvent might be a factor in preventing attack. The following tabulation of results of six replications of 24 samples each shows that DDT was effective with either one or two applications, but the petroleum solvent did not act as a repellent.

Treatment	Live parent beetles	Live progeny	Egg galleries	
			No./ sq. ft.	*In./ sq. ft.*
	Per sq. ft.	*Per sq. ft.*		
2% DDT, once	0	1.7	2.9	1.2
2% DDT, twice	0	7.1	0	0
2% Solvent, twice	5.8	251.7	21.7	50.2
Not sprayed	1.2	127.9	15.4	40.9

Attracting Beetles.—Toxic sprays treat infested material effectively but they are expensive. If beetles could be attracted to accessible locations where infested trees could be logged, treatment would be more effective and cheaper. One drawback to attracting Douglas-fir beetles into trap logs is that density of attack tends to be less than one-half that in naturally infested standing trees. Second, beetles usually attack the shaded underside of logs. This year we started experimental attempts to intensify attacks and to get better distribution of beetles around the circumference so that fewer trap trees would be needed. Our experiments included standing trap trees as well as shaded felled trees.

In one test, fresh-cut slabs from Douglas-fir were fastened to 15 trees at a height of 10 feet. Five of the slabs were covered with screen to prevent their becoming infested. The other slabs were infested artificially with adult Douglas-fir beetles. The objective was to compare the relative attractiveness of fresh-cut uninfested phloem with that of recently infested phloem. Eleven of the fifteen trees to which slabs were attached showed beetle attack. The beetles displayed a 2.5:1 preference for trees bearing infested slabs. At two locations, attacking beetles "spilled over" into nine nearby trees. No such attacks occurred in replicates where bait trees remained free of infestation.

More than one-half of attacks in the bait trees were unsuccessful, and the length of infested stem was short. While comparatively few beetles were trapped, we are encouraged by results of these preliminary tests. By selecting older trees for traps, considered less resistant, we should increase the number of successful attacks. The attractive material might be duplicated without having to cut and fasten slabs to trees. Eventually an attractant may be isolated or synthesized for use in trap studies.



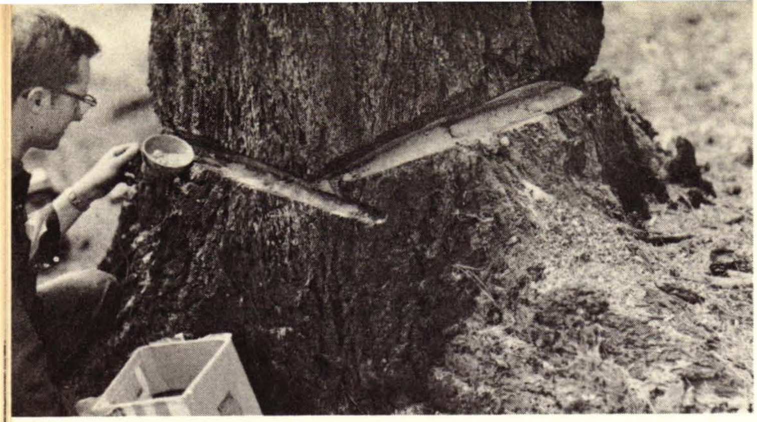
Bark samples cut from beetle-infested trees with newly developed 1/10-sq. ft. punch.

In another test, 30 trees were treated by three methods prior to flight of beetles from infested trees. Ten trees were felled and shaded

Treatment	Samples	Live brood survival (av.)	Egg galleries[1]	
			Av. number	Av. length
		Per sq. ft.	*Per sq. ft.*	*In. per sq. ft.*
Ammate, standing	138	13.0	16.2	41.7
2,4-D, standing	122	50.6	16.2	38.2
Felled, shaded	176	47.0	15.9	36.3

[1] Intercepted by bark punch samples.

Fresh-cut Douglas-fir slabs fastened to live trap trees to attract bark beetles. Screen prevented infestation of slabs.



Application of ammate crystals to kill standing trees for comparison of standing trap trees with felled trees.

with lopped limbs, 10 standing trees were killed with ammate crystals, and 10 standing trees were killed with 2,4-D herbicide. Initially, felled traps received more attacks, but the chemically treated standing trap trees eventually absorbed an equal number of attacks as shown in the tabulation (p. 15). Some of these later attacks may have been made by parent adult beetles that first attacked felled traps and then attacked a standing tree a second time. The low brood survival in ammate-treated trees appeared to result from rapid drying of the inner bark.

Equal numbers of felled, shaded trap trees received more attacks than did standing traps. In spite of this fact, results with standing trap trees were sufficiently good to justify further tests to develop traps that would be more effective as well as cheaper and easier to prepare than felled, shaded trees. Time of treatment and dosage are variables that need study. Maximum distance of attraction must be determined, for success with trap material depends upon the development of a practical method of placement within forest stands.

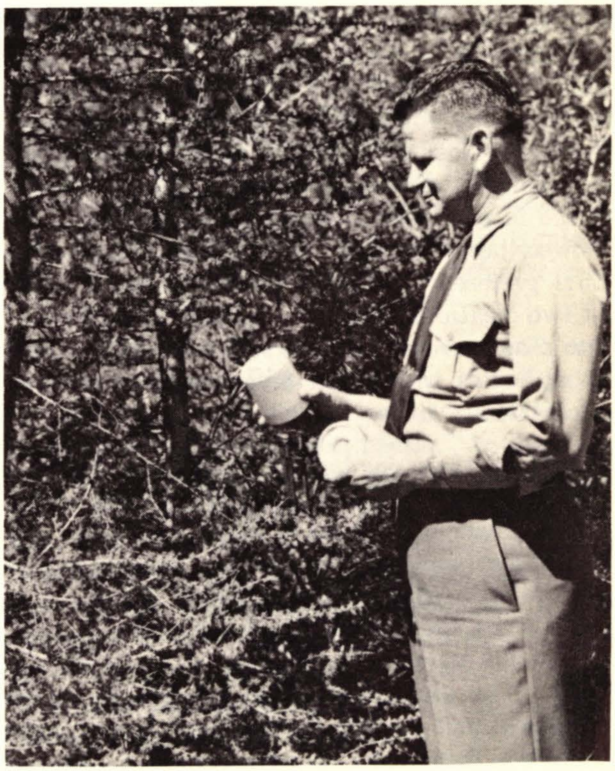
Larch Casebearer

Area Attacked.—The larch casebearer, *Coleophora laricella* (Hbn.), a pest of American larch (tamarack) for many years in the eastern United States, was discovered in western larch forests in 1957 near St. Maries, Idaho. No one knows how the casebearer was introduced into the western area but nearest known infestations to the east are in the Lake States. Surveys in all directions from St. Maries show that noticeable feeding by the casebearer covers about 530 square miles and that the pest is established throughout northern Idaho and parts of eastern Washington.

Rearings of casebearer larvae revealed practically no parasitism—less than 1 percent—in the populations examined to date. Since the casebearer is a recent introduction and is attacking a new host, there is considerable interest in the possible course of the infestation and damage pattern.

Biological Control.—A braconid parasite, *Agathis pumilus*, introduced from Europe has become established in eastern infestations of casebearer and is a valuable natural control agent. During 1960, approximately 2,400 of these parasites were liberated near St. Maries. The parasites were collected and shipped by personnel of the Northeastern Forest Experiment Station.

Presence of the casebearer in a new area and on a new plant host offers excellent opportunity to test the effectiveness of biological control by introduction of a single species of parasite. Collections of larch casebearer will be made in 1961 at each release point to determine whether establishment was accomplished. If parasites have become established, future work can develop significant parasite-host relationships where a pest has recently invaded a new area.



Releasing *Agathis pumilus* in infested larch stand near St. Maries, Idaho.

Promising Biological Insecticide

During the past few years there has been considerable interest in the use of a bacterium, *Bacillus thuringiensis* Berliner, as an insecticide. There are advantages because the bacterium seems to be specific among the insect species that show susceptibility, and it is apparently nontoxic to man and other warmblooded animals, birds, fish, and plants.

B. thuringiensis has been tested against numerous pests of agricultural crops. Because it controlled many types of caterpillars on various crops it was considered desirable to conduct limited tests to determine possible use of the material against forest insects. The presence of populations of Great Basin tent caterpillar, *Malacosoma fragilis* (Stretch) near Zion National Park in southern Utah, furnished opportunity to test the bacterium.

Bacillus was applied as a wettable powder containing 3 billion spores per gram at rates of 0.5, 1, 2, and 4 pounds per acre. The suspension was applied to foliage of serviceberrry, *Amelanchier utahensis*, surrounding caterpillar tents. A small hand-held pressure sprayer commonly used in service stations to apply windshield cleaner was adapted for use in this study. One hundred milliliters of a given dilution was applied to simulate a rate of 1 gallon per acre as nearly as possible. Sprayed branches were enclosed in sleeve cages which facilitated periodic counts and examination of larvae. Check cages were installed on nearby untreated shrubs.

All dosages produced satisfactory mortality, ranging from 90.9 to 100 percent. Shaded cages showed less mortality than exposed cages. Mortality is associated with rate of ingestion of spores, and feeding by larvae in shaded cages proceeded much slower than in sun-lighted cages. Results obtained show that *B. thuringiensis* can be used to control the Great Basin tent caterpillar. Methods for applying material over extensive areas would require additional experimentation.

SURVEY TECHNIQUES IMPROVED

Mountain Pine Beetle Study

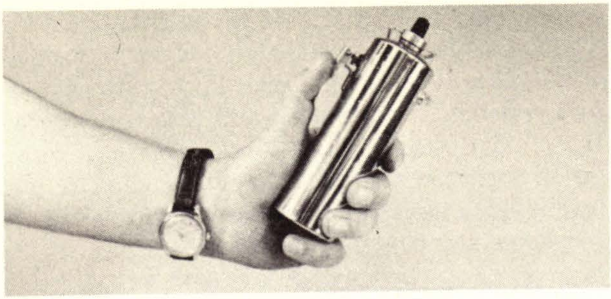
Data were collected during chemical control operations and in connection with biological evaluations of outbreaks of mountain pine beetle in lodgepole pine from 1956 through 1959 on the Teton, Ashley, and Wasatch National Forests and in Grand Teton National Park. Tree diameters and height of attack were recorded for 749 trees. Analyses of data showed a definite correlation between diameter at breast height and height of attack by mountain pine beetle in lodgepole stands.

Hand-operated spray pumps and extension rods now in use provide effective spray coverage to a height of 27.5 feet on standing trees. Of all trees sampled, 46 percent had attack above the effective spray limit. In the 8- to 9-inch diameter class only 6 percent of the trees had infestation above the spray limit, while in trees 14 inches and larger in diameter, this percentage approximated two-thirds. This information is valuable in planning chemical control operations against this bark beetle in lodgepole pine. Knowledge of size of infested trees to be treated indicates extent felling may be necessary to insure proper treatment. (Full analyses of data are published in Intermountain Forest and Range Experiment Station Research Note 78).

Tussock Moth Control--Pilot Test

Putting research results into practice often requires an intermediate step before complete adoption as an accepted procedure. Such pilot tests are particularly necessary in the relationship between forest insect research, insect survey

Flexiglass and saran screen sleeve cage encloses larvae of Great Basin tent caterpillar on foliage.



Pressure sprayer used to apply bacillus in tent caterpillar control experiments.

and evaluation activities, and control practice by forest managers.

A cooperatively planned and executed pilot test was carried out this year by station entomologists and personnel of the Timber Management Division in Region 4. Virus material in a carrier solution was sprayed by airplane on a stand of white fir infested with tussock moth near Wheeler Peak on the Humboldt National Forest, Nevada.

The epidemic of tussock moth, about 5,000 acres in size, was discovered late in 1959. Damage was so severe that control action was needed to avoid serious killing in 1960. A generically specific virus was available from rearings of tussock moth larvae in the laboratory, and a decision was made to attempt control with this disease organism. Laboratory work had indicated that the species was susceptible.

Seven plots were established, five for treatments and two for checks. The material was applied in equal amounts of carrier solution at three concentrations of virus polyhedra: 2.5×10^8, 5.0×10^8, and 10.0×10^8. Aerial application was set at 1 gallon per acre. The carrier solution consisted of 0.9 gallon water, 0.1 gallon corn syrup (to inhibit evaporation during application), and 0.01 gallon of Leucophor C, a fluorescent tracer. This basic formula contained 1 milliliter of virus concentrate. The carrier solution without virus was applied to check plots.

Spray deposit cards examined by ultraviolet light revealed the extent of coverage by the fluorescence of the Leucophor C. Spray droplets were easily counted on foliage and bark of trees, as well as on cards, under the "black light."

All three virus concentrations produced mortality within known populations in cages applied to branches following spraying. There was no apparent difference in mortality in plots receiving deposits between 5.0×10^8 and 10.0×10^8 polyhedra per acre. Droplet counts from caged material indicated that 0.71 to 4.18×10^8 polyhedra per acre would produce 50-percent mortality. It was also calculated that a dosage of 70.0×10^8 would be required to produce an average of 84-percent mortality. This high concentration of virus material might not be economically feasible in large-scale applications. Unlike chemical insecticides, virus can persist after application and remain active in subsequent populations. Thus, it is not as essential to obtain an extremely high degree of kill with the original application.

The mortality obtained during this pilot test ranged from 39 to 71 percent. We believe that there is evidence of virus establishment at a level that will reduce populations to a point that little damage will occur during 1961. Examinations at that time will reveal the soundness of the prediction.

SURVEYS

Detection and evaluation of forest insect populations in Intermountain Station territory during 1960 revealed numerous serious outbreaks. Cooperation received from Federal, State, and private land managers extended the effectiveness of the entomologists in determining the status of over-all insect infestations. Only the more important infestations are reported here.

Bark Beetles

In northern Rocky Mountain states, damage from bark beetles remains relatively low. The number of Douglas-fir trees killed by Douglas-fir beetle, *Dendroctonus pseudotsugae*, Hopk., increased, and outbreak conditions may be developing. Outbreaks of western pine beetle, *D. brevicomis* Lec., increased in number in northern Idaho and western Montana during the year. Although no serious outbreaks were reported, infested trees were more noticeable in several areas. Mountain pine beetle, *D. monticolae* Hopk., continues to cause considerable tree mortality in old-growth western pine stands in northern Idaho.

Several species of bark beetles are causing extremely heavy losses in the Intermountain area. Mountain pine beetle outbreaks are present in northern Utah, eastern Idaho, and western

Wyoming. Twenty-two infestation centers in lodgepole pine stands recorded in 1960 ranged in size from a few hundred to 280,000 trees. This pest is also active in second-growth ponderosa pine on the north shore of Lake Tahoe, Nevada, and in a second-growth stand in southern Idaho.

Several serious outbreaks of Engelmann spruce beetle, *Dendroctonus engelmanni* Hopk., have developed in southern Idaho, Utah, and western Wyoming during the past few years. Control action reduced populations in some areas, but two outbreaks in Utah and Wyoming are still serious.

Rather large volumes of Douglas-fir are killed by the Douglas-fir beetle each year in the Intermountain states. This bark beetle is active throughout the area, with many epidemic centers in two locations, one in southern Idaho and another in southern Utah. Damage is less in other areas but numerous centers of infestation have been recorded.

Defoliators

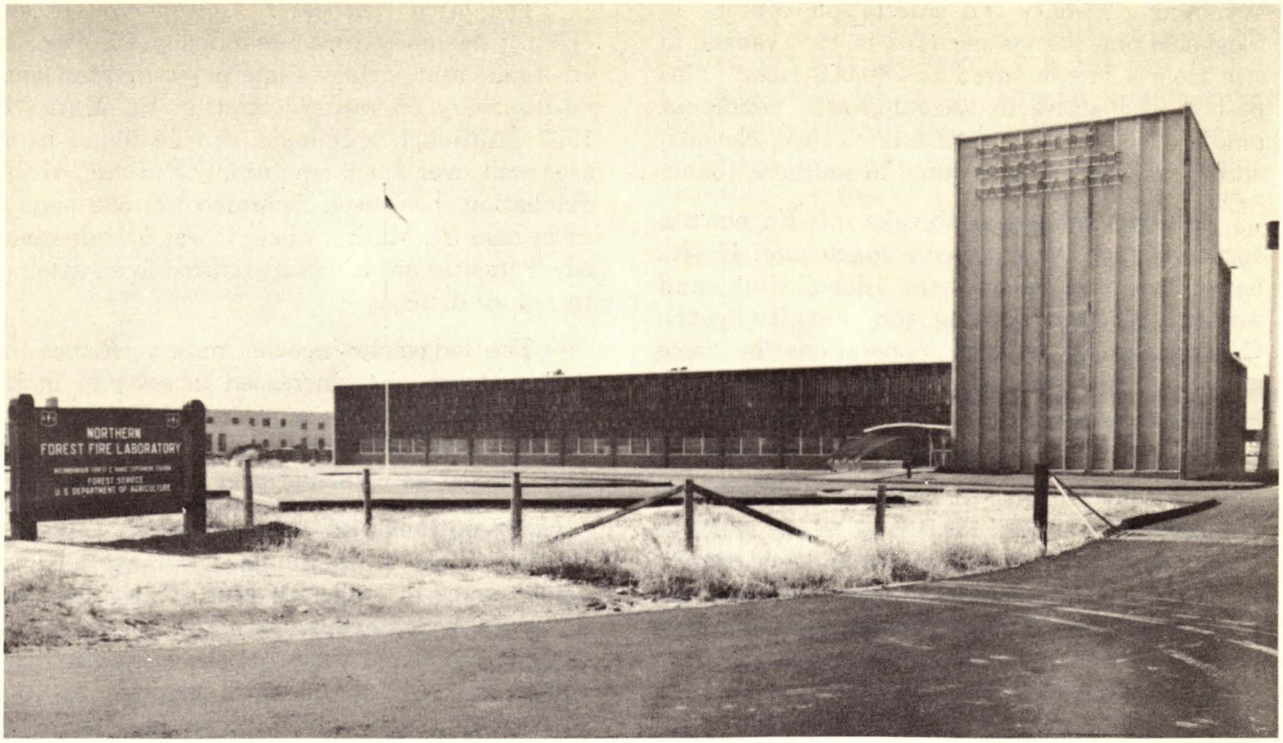
Defoliators are active in several forest types. The spruce budworm, *Choristoneura fumiferana* (Clem.), continues in epidemic status over large areas in Montana and southern Idaho. Infested acreage in Montana did not increase appreciably, nor did severity of defoliation significantly decrease. In southern Idaho, populations have decreased generally, with two minor exceptions.

The larch casebearer, *Coleophora laricella* (Hbn.), has spread over practically all of northern Idaho and parts of eastern Washington since its discovery on western larch at St. Maries in 1957. Although specimens can be found in an area well over 8,000 square miles in size, visible defoliation has been confined to 532 square miles near St. Maries, where it was first discovered. Parasites are being introduced in an attempt to reduce damage.

The lodgepole needle miner, *Recurvaria milleri* Busck., has increased in severity in the lodgepole pine forests in parts of Idaho and Wyoming during the past 4 years. Infestations are now classed as epidemic over 200,000 acres.

An outbreak of pandora moth, *Coloradia pandora* Blake, near Manila, Utah, extends over 15,000 acres of lodgepole pine. This insect has a 2-year cycle; heavy larval feeding occurs in the odd-numbered years. If the infestation continues in 1961 at the level observed in 1959, severe defoliation may be expected. The trend of the infestation will be determined early in 1961.

There were numerous less serious infestations of engraver beetles, tussock moths, sawflies, shoot moths, mealybugs, and aphids on various host species. The over-all forest insect situation in the Intermountain Station territory continues to be a serious factor in the management of forest stands.



Northern Forest Fire Laboratory, dedicated September 12.

FOREST FIRE RESEARCH

The 1960 fire season in the West again emphasized the magnitude and complexity of regional forest fire control. Critically dry weather from mid-June through July created fire emergencies in many forests. Nearly 1,000 lightning fires started in Intermountain forests during July. A single storm started 118 fires in one national forest. Several major fires necessitated the greatest mobilization of fire-fighting forces of the past decade. Total damage was severe. Fortunately, rains in early August eased the situation for the latter part of the fire season.

Several events of the 1960 fire season focused attention on the importance of fire science and on the needs and challenges of forest fire research. They renewed emphasis on the importance of many high priority targets for research: outbreaks of hundreds of lightning fires, an increasing number of man-made fires, suppression of violent fires that could not be stopped by presently known methods, prediction of fire behavior, reduction of hazards, and both aerial and ground attack on fires with chemicals.

NORTHERN FOREST FIRE LABORATORY

Dedication and Operation

The Northern Forest Fire Laboratory was formally dedicated on September 12. In an impressive ceremony, Dr. Richard E. McArdle, Chief of the Forest Service, presented the keys of the new laboratory to Director Bailey of Intermountain Station. Other speakers at the ceremony included Congressman (now U. S. Senator) Lee Metcalf and Station Director Reed W. Bailey. Jack Barrows, chief of the station's division of Forest Fire Research, was in charge of arrangements and presided over the program.

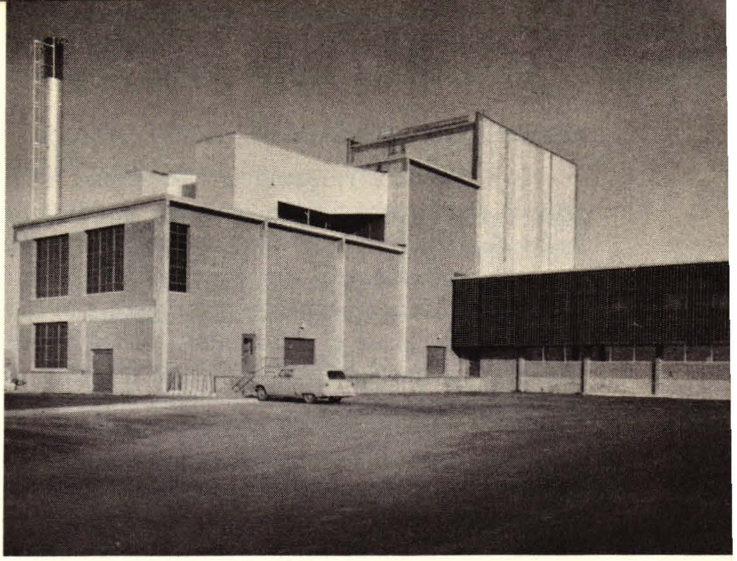
Attending the dedication and open house were representatives from cooperating private, State and Federal agencies, universities, many local citizens, and State foresters from throughout the Nation who were holding their national convention in Missoula. Immediately following the dedication, a World Forestry Congress tour group of 80 delegates from 22 countries visited the laboratory and the adjacent Northern Region Aerial Fire Depot.

In October, the Division of Forest Fire Research moved into the laboratory and began operations. Technical personnel had to continue installation of equipment and start calibrating and testing numerous instruments and control systems. At the end of the year, basic equipment had been installed in the physics and chemistry laboratories, and calibration of the instrument systems in the combustion studies wing was under way. The first combustion experiments are scheduled for early spring in 1961.

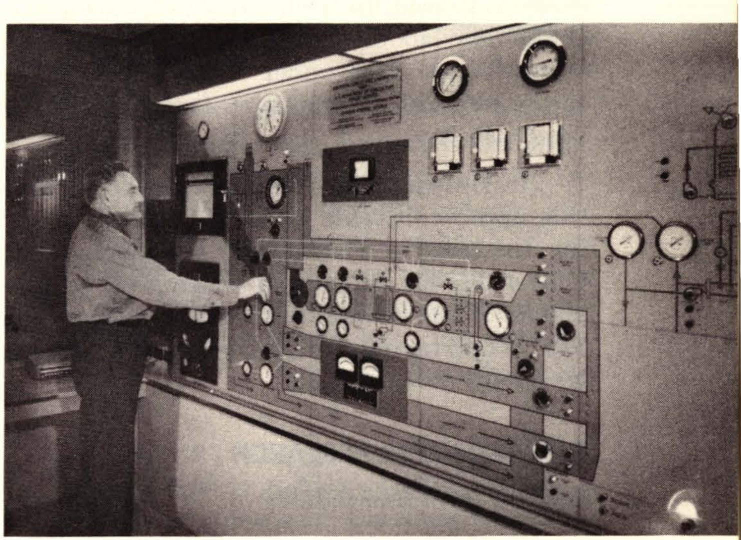
Radar will be one important scientific tool available for research in lightning fire and forest fire meteorology. Installation of a powerful weather radar unit for a joint U. S. Weather Bureau-Forest Service project continued on Point 6, an 8,000-foot peak near Missoula. Next year the U. S. Weather Bureau will construct a special building on the peak, will install the weather radar transmitter, microwave relay equipment, and receiver systems at the airport fire weather forecasting center and the fire laboratory. Then the Weather Bureau forecasters and Forest Service research meteorologists can use radar scopes to detect, track, and analyze lightning storms and other atmospheric phenomena related to fire weather over a radius of some 250 miles from Missoula.

Research Planning

Research planning and the development of coordination procedures with other research units and cooperating agencies was a major activity during 1960. We participated in a National Fire Research planning conference at the Southern Forest Fire Laboratory, Macon, Georgia. Other participating agencies were the forest fire laboratory staff at Macon, the projected Western Forest Fire Laboratory in California, and fire research groups from other Forest Service experiment stations. Additional research planning and coordination were undertaken in cooperation with the National Science Foundation, U. S. Weather Bureau, Bureau of Land Management, National Forest Administration, Washington State University, and the Western Fire Research Committee of the Western Forestry and Conservation Association. This planning has produced better understanding of research problems and procedures, and it results in better opportunity to stretch the research dollar in coordinated programs.

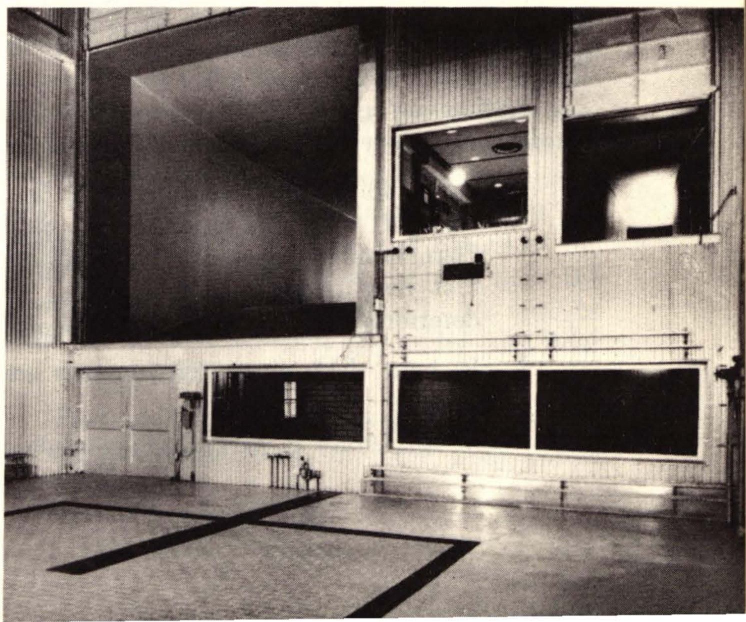


Exterior view of wind tunnels and combustion research unit.



Control panel for wind tunnels and combustion laboratory.

Combustion laboratory, showing entrance to wind tunnels and viewing rooms.



FIRE PHYSICS RESEARCH

Fire physics research is the phase of fire science that concerns the ignition, buildup, and basic characteristics of free-burning fires. This research investigates the fundamental natural laws that govern unconfined combustion in order to add to the store of information about fire that will give us new ability to control wildfires and to use fire beneficially.

Our major effort in fire physics to date has been investigation of fundamental problems, basic research techniques, and methods of experimenting. In cooperation with other groups, we have investigated the use of visual, diagnostic, and functional models as means for laboratory studies of basic fire characteristics. Completion of the new laboratory makes possible the study of small-scale fires under controlled conditions of temperature, air moisture, fuel moisture, and wind velocity.

In December, the National Science Foundation approved grants to this laboratory and to the Institute of Technology, Washington State University, for support of cooperative basic research of the mechanisms of fire spread. This joint undertaking will include both field and laboratory investigations.

FIRE BEHAVIOR RESEARCH

Logging Slash Flammability

Field investigations of logging slash flammability were completed at Priest River Experimental Forest in 1960. Final experiments involved the burning of 5-year-old plots to test the effect of age of various species and amounts of logging slash fuels on flammability. Previously we had burned fresh and 1-year-old slash. Results of the earlier experimental burnings were published this year.[6]

Preliminary results of studies of the flammability of 5-year-old logging slash indicate:

1. Flammability is generally lower in 5-year-old than in recently cut slash. Flammability decreases most during the first year following timber cutting, and deterioration is much slower thereafter.
2. In light slash plots (7.5 tons per acre, dry weight) fuels deteriorated so much in 5 years that fire spread was slight.
3. In medium and heavy slash plots (20 and 32.5 tons per acre, dry weight, respectively) fires spread at moderate rates and burned with considerable intensity. When sufficient dry fuel is present in medium and heavy slash plots, aging for 5 years does not reduce flammability of all species to low levels.

Fire-Danger Rating

Fuel Moisture Studies.—At Priest River Experimental Forest we have been studying the moisture content of large logs as a possible element in fire-danger rating, especially as an element in gaging the severity of a fire season. Original plans called for continuation of this study until both easy and severe fire seasons had been experienced. The severe fire weather of late June and July 1960 permitted completion of this study. Taking of final field data on October 25 marked the termination of 19 years of productive investigations of fire danger in heavy fuels.

The large log fuel moisture studies have shown that heavy fuels reach various degrees of flammability according to the interactions of prolonged weather trends and, to a lesser extent, according to daily variations in weather. This knowledge has already helped in designing some regional fire-danger rating systems and should also help in designing the projected national fire-danger rating system.

A second basic factor is the relation of moisture in fine fuels to fire danger. Fine fuels absorb and lose moisture much more rapidly than large logs. Studies of fine fuel moisture relations have been under way at both the Priest River and Boise Basin Experimental Forests; laboratory studies will start soon. Fuel temperature and fuel moisture in fine fuels are being investigated in relation to air temperature, relative humidity, and the moisture content registered by standard fuel moisture indicators at fire weather stations.

Instrumentation.—Proper instrumentation is basic to this research and will be equally vital to eventual practical application at fire weather stations gathering data for operational fire-danger rating systems. In fuel moisture research, in-

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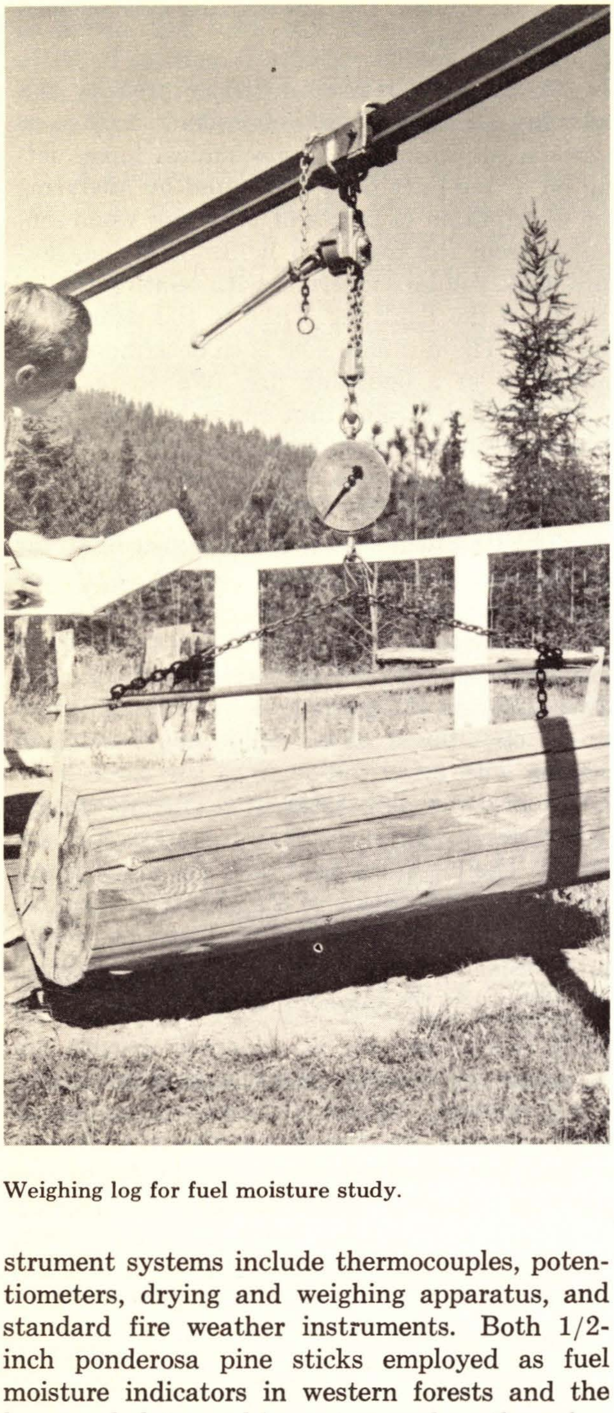
[6] See Fahnestock, George R., in Publications section.



Weighing log for fuel moisture study.

strument systems include thermocouples, potentiometers, drying and weighing apparatus, and standard fire weather instruments. Both 1/2-inch ponderosa pine sticks employed as fuel moisture indicators in western forests and the basswood slats used in eastern and southern forests are being investigated in relation to actual moisture content of fine fuels. When final operational instrument requirements are determined, we expect to explore the use of both manually operated and automatic recording instruments for fire-danger rating. These instrument systems can be fashioned from prototypes already developed and reported by the Northern Forest Fire Laboratory.

Results.—Preliminary results of our studies of moisture content in fine fuels indicate:

1. Fine fuels (*e.g.*, cured cheatgrass) have extremely short time lag constants for rate of moisture gain or loss—possibly measured in minutes.
2. Proper measurement of fuel temperature may reflect the effect of incoming solar radiation during the day and emitted radiation at night without the complication of handling radiation measurements separately.
3. Temperature may be the most important variable determining moisture content of fine fuels. Fuel temperature changes often lead air temperature changes.
4. During long periods of hot dry weather with no daily dew formation, the afternoon moisture content differences between standard indicator sticks and slats and fine fuels may be small. When diurnal changes become greater or when dew forms, the afternoon moisture content differences between standard indicators and fine fuels may be quite large.
5. The rate of change of moisture content is related to surface-to-volume ratio in fuels or indicators. Standard fuel moisture indicator slats respond to changes faster than sticks because slats have a greater surface-to-volume ratio.

Prescribed Burning Research

Our research in prescribed burning aims to: (1) determine when to burn to achieve specific results in forest management and (2) develop techniques for using fire to achieve these results. These are primarily problems in fire behavior. Analyses indicate the need to develop techniques that will permit use of fire under weather conditions previously considered unsatisfactory for prescribed burning. The site and nature of the prescribed burning operation require that the season for use of fire be extended. We need to learn how to burn satisfactorily under both drier and wetter conditions.

Part of the research data for prescribed burning investigation must come from actual field operations. In cooperation with Region 1, we have devised an individual fire report for prescribed burns, designed for transfer of data to punch cards for machine analyses. Use of this form is expected to provide much needed information on the nature, magnitude, and results of various types of prescribed burning.

Fire Spread Research

National Science Foundation support for cooperative study of the mechanisms of fire spread has enabled us to start new work in this important field. Instrument systems and research techniques will be developed for studying fire spread at the scene of both wildfires and prescribed burns. Research teams will go to fires to investigate specific rates and means of fire spread as related to atmospheric and fuel environments. These field investigations should yield data on specific ranges of some fire spread factors that will be a basis for controlled experiments in the laboratory.

During the 1960 season, forest fire laboratory personnel observed fire behavior at several large fires, both wildfires and prescribed burning operations in Forest Service Regions 1 and 4.

FOREST FIRE METEOROLOGY

Forest fire meteorology concerns the relation of atmospheric phenomena to the ignition, spread, and control of fires. Our major effort in this branch of research has been directed towards the lightning fire problem. Project Skyfire continues research on the characteristics of lightning storms that affect the ignition of lightning fires and also the effect of weather modification techniques on lightning storms.

Lightning Storm Characteristics

Survey of the regionwide occurrence of lightning storms and strikes was expanded during the past fire season. Data taken over several years now show a pattern of storm behavior in the northern Rocky Mountain region. Correlation of lightning strike density with lightning fire occurrence has shown that in some areas more than 6 percent of the cloud-to-ground lightning strikes cause fires whereas in most areas fewer than 1 percent of the strikes result in reportable lightning fires. Further study should help determine the weather and fuel variables that control the fire-starting efficiency of lightning strikes.

Study of the relation between intensity of a lightning strike and the subsequent damage to a tree is continuing. The mechanical forces acting on a tree have been calculated by analyzing the distribution of pieces of bark and wood separated from the tree by a lightning strike. Future work will be concerned with relating the intensity of the lightning strike to the damage to the tree. The ultimate goal is to determine what factors cause a lightning fire. We do not now know whether strikes that cause fires are more intense than those that do not.

Lightning Modification Experiments

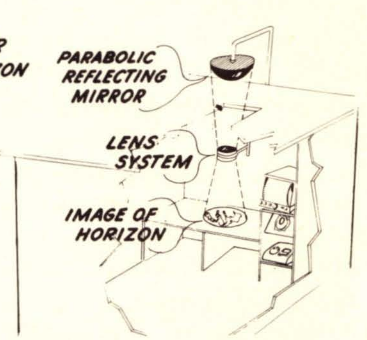
The first field season of a 2½-year lightning modification research program jointly supported by the National Science Foundation and the Forest Service was completed this year. Field measurements of the electrical and physical characteristics of lightning storms were obtained on 16 operational days. Sixty hours of cloud seeding with silver iodide from two aircraft resulted in seven pairs of treated and nontreated thunderstorm days suitable for statistical analysis. The electrical field data are being transcribed for computation of the electrical variables for each storm. In addition, photographs, weather records, and radar data are being analyzed to reconstruct the meteorological events for each operational day.

Prior to the field season, a statistical model was developed that will determine the effect of cloud seeding on the frequency of lightning strikes, the electrical properties of discharges, and the physical characteristics of thunder-

LIGHTNING SPOTTING SYSTEM

WITH THIS DEVICE, AN OBSERVER CAN SEE OVER THE ENTIRE 360° HORIZON AT THE SAME TIME.

ACCURATE BEARINGS ON CLOUD-TO-GROUND STRIKES FROM TWO OR MORE OF THESE LENS SYSTEMS ARE USED TO OBTAIN THE EXACT LOCATION OF ANY PARTICULAR STRIKE.



storms. Simple nonparametric procedures, such as signed rank tests, will be used to evaluate the effect of seeding. Probably at least two seasons' data will be needed as basis for conclusions on the effect of cloud seeding on lightning storms.

A simple electrical model of a thunderstorm has been adopted for the evaluation program. A set of simultaneous equations based on this model has been derived to describe the electrical properties of simple cloud-to-ground lightning strikes. A more complex mathematical model will be studied to utilize the data from a range-height radar available for the 1961 field season.

The problem of spotting the location of lightning strikes in the area around a lookout station has been solved by development of a spotting system. This system consists of a parabolic reflector mounted on a shelter, a lens system, and a plotting board. The lens system projects the image of lightning strikes onto a polar grid mounted in front of the observer. This system gives the observer complete surveillance of the horizon.

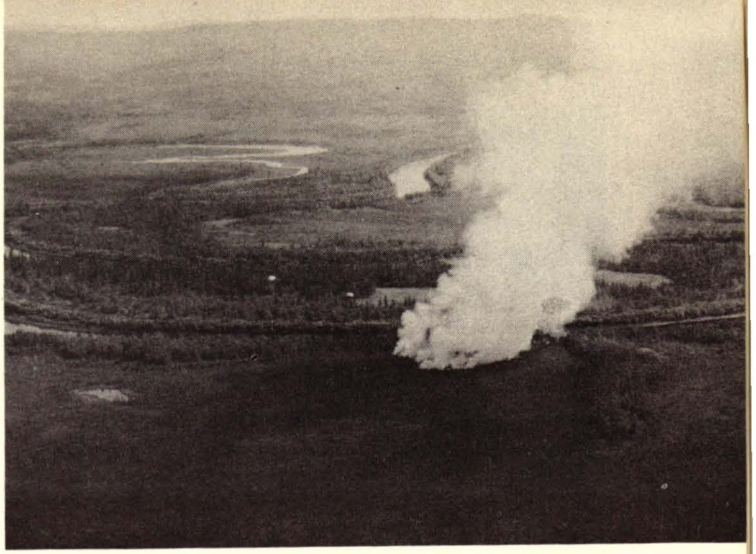
FIRE CONTROL RESEARCH

Fire control research is entering a new era at the Northern Forest Fire Laboratory. Future research will include projects in prevention of man-caused fires, fire detection, techniques, equipment and materials (including chemicals) for fire suppression, and operations analyses of fire control systems. At present we are giving priority to completion of existing equipment research, initial work on special features of fire control in Alaska, and especially to the detection of lightning fires.

Alaska Project

A comprehensive analysis of the forest fire problem in Alaska is nearing completion. The final report is not yet published, but the results of our investigations already have been used extensively in delineating the research studies requiring early solution.

A full time research forester, a staff member of the Alaska Forest Research Center, will start an on-the-ground fire research program in Interior Alaska in 1961. Technical assistance and special supporting services for the program will be provided by the Northern Forest Fire Laboratory. Alaskan fuels will be tested for flammability and rate of spread. We shall also set up model fire behavior studies and continue the development of special equipment and instruments necessary for Alaskan conditions.

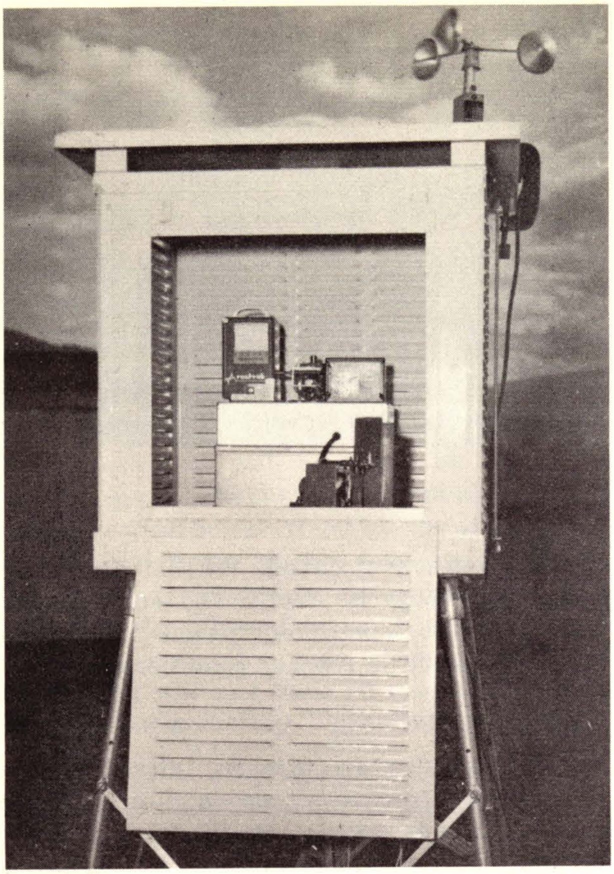


Aerial view of lightning fire in Alaska.

Lightning Fire Detection

Lightning-caused fires in Interior Alaska are only 24 percent of the total fires in the State, but they account for 76 percent of the acreage burned. Two-thirds of the lightning fires burn more than 300 acres each, while less than 10 percent of man-caused fires exceed this size. One reason for this disparity is that when present detection methods are applied to such vast areas with extremely limited facilities, 2 or 3 days sometimes elapse between discovery and reporting of a fire. A system of detection that will speed up initial attack of lightning fires should drastically decrease the acreage burned. An indirect approach to early detection of lightning fires is to track lightning storms by a combination of radar and sferics receivers and to report the active cells to patrol aircraft. In this manner a minimum amount of air patrol will be able to concentrate on areas having high lightning incidence.

Since we need much faster detection of lightning fires, we are starting development and testing of electronic systems for storm tracking. Equipment will be fashioned primarily from surplus military gear, including marine beach radar sets and radio direction finder units. When the equipment and techniques have been developed to a satisfactory performance level, the system will be moved to Alaska for full-scale operational tests.



Automatic recording fire weather station developed at Northern Forest Fire Laboratory.

Fire Equipment Research

Development of instruments and equipment for fire research and fire control is a continuous program. However, a project during the last few years aimed at developing new instruments and modifying existing ones for fire-danger rating is drawing to a close.

Completed and on the market now are a totalizing wind counter for contacting type anemometers; an aluminum rain gage and plastic measuring stick; and a belt weather kit containing a psychrometer, wind meter, and accessories needed in weather measurements at the site of fires. Submitted for final approval is a small electric fan psychrometer assembly. Satisfactorily tested in the laboratory and in the open under field conditions and now ready for final writeup and approval are a photo-recording fire weather station, a continuous recording fire weather station, a knockdown aluminum instrument shelter, and a portable fire weather station. Still being developed is an atmospheric stability indicator to be attached to the wing or strut of an airplane, and a lightning strike counter. We shall maintain constant search for new instruments and try to develop those needed but not produced commercially that will be valuable for more effective fire research and control.

FOREST ECONOMICS RESEARCH

The program of the Division of Forest Economics Research was broadened in 1960 to provide more specific information on the quality and condition of timber resources in our territory. Forest Survey and forest economics staffs cooperated in developing and testing procedures for better describing the silvicultural condition of timber stands and for determining the management measures required to increase productivity. Forest Survey also started a study to determine the wood density of the Rocky Mountain species from increment cores. All these projects will result in a much better understanding of our forest situation and of the management programs needed.

FOREST SURVEY

The field inventory phase of the initial Forest Survey of Region 2 was completed in the 1960 field season. Eight survey crews completed the inventory of sample locations on the Shoshone and Black Hills National Forests, the remaining portion of the Medicine Bow National Forest, and all of the land area outside national forest boundaries in Wyoming and western South Dakota. The commercial forest area covered about 3.3 million acres. This has been a cooperative project with the Division of Timber Management of Region 2 and the national forests. Region 2 is compiling the area data on the national forests inventoried by survey crews.

Work progressed on reinventory of northern Idaho, and plot work in Benewah and Latah Counties was completed. In cooperation with Region 1, we shall extend field work in northern Idaho in 1961 to the Kaniksu National Forest and to Boundary and Bonner Counties.

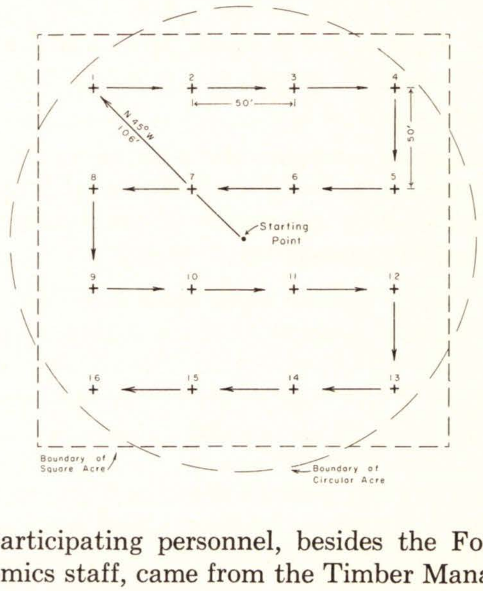
Compilations of area, volume, and growth on the reinventory of western Montana are being completed by the data processing unit at the Pacific Southwest Forest and Range Experiment Station at Berkeley, California.

In cooperation with Region 4, the Forest Survey will extend the initial survey coverage next season to Utah and Nevada. Region 4 has completed inventory of most of the national forests in both States, and the Forest Survey will cover all the remaining unsurveyed public and private lands.

In 1960 a new national handbook for the Forest Survey was completed establishing standard definitions and setting up basic data requirements and accuracy standards for all Forest Survey units. This new handbook signals a broadening of the scope of the Forest Survey program to include data on the condition of timber stands as a basis for prescribing management needs in addition to area and volume data. Changes in standard field procedure were needed to obtain information to fulfill these additional requirements. Several procedures were considered and tested briefly in the field before we developd a method that seems to meet our needs for adequately describing stand conditions while providing inventory information. To test this procedure, a pilot study was made on the St. Regis District of the Coeur d'Alene National Forest in Montana.

The system developed consists of a series of 16 small plots systematically distributed over an acre. At each point, a record is made of all trees within a 1/256-acre plot. The condition of dominant trees on each plot is described in detail and the number and size of excess trees are recorded. In addition, information is recorded on all sawtimber trees within the range of a 75-factor prism at each point to obtain an adequate sample of sawtimber volume.

LAYOUT OF PLOT GRID



Participating personnel, besides the Forest Economics staff, came from the Timber Management Divisions of Regions 1 and 2; from the

Economics Research Divisions of the Rocky Mountain, Pacific Northwest, and Southern Stations; and from the Forest Management Research Division of the Intermountain Station. Data collected on about 130 sample locations are now being compiled and analyzed. The conclusions will guide development of a survey system that will best describe the condition of forest stands and will also provide inventory data at the desired accuracy level.

Wood Density Survey

At the start of fiscal year 1961 the Forest Survey in this region was given the added responsibility of devising a sampling system and of collecting increment core samples and related data for a wood density survey of western softwoods. This study is being made in cooperation with the Forest Products Laboratory and is part of wood density surveys now under way in other parts of the country.

Past research has shown a relationship between the specific gravity of an increment core taken at breast height to the specific gravity of the entire merchantable portion of the tree. This makes possible a mass sampling of tree species over a large area in a relatively short time. The primary objective of the wood density survey is to obtain adequate data on the average wood density of each species, the magnitude of the differences between species, and the range of variation within species. The survey will also provide valuable information about the extent to which wood density varies with tree age, growth rate, stand basal area, latitude, longitude, altitude, aspect, and other factors.

Results of the study will be used to develop more adequate strength values for species just beginning to be utilized on a large scale and to fill gaps in information about species not yet adequately sampled.

Wood density cores were collected in 1960 by Forest Survey crews on regular inventory plots in Wyoming, South Dakota, and northern Idaho. Wood density survey project crews collected cores in western Montana. National forest timber inventory crews cooperated by collecting increment cores in northern Idaho and Utah. Nearly 3,000 cores were obtained and sent to the Forest Products Laboratory for processing and analysis.

In 1961, wood density project crews will complete a sample survey in Wyoming, Utah, and Nevada and will continue taking core samples in western Montana. Forest Survey crews and NFA timber management inventory crews also will collect cores on inventory plots in Utah, Nevada, and Idaho.

Timber Cut

Annual surveys of the production of commercial poles in the northern Rocky Mountain area and of exports of Christmas trees from Montana showed encouraging upswings for 1959 from the corresponding figures for 1958. Commercial pole production totaled 428,581 poles, an increase of 26 percent over 1958. Christmas tree exports from Montana reached 3.8 million trees, the second highest volume on record. These changes were recognized as reflections of a general recovery by forest industries from the general business recession of 1957-58. The annual survey of the pole industry is conducted in cooperation with the Rocky Mountain Pole and Treating Association, and the Christmas tree survey in cooperation with the transstate railroads in Montana and with State and Federal agencies.

The 1959 pulpwood production, as measured by plant receipts of roundwood, was 131,850 standard cords in Idaho and 46,750 cords in Montana—a 50-percent reduction from 1956, the preceding survey year. This decline is attributed to a greater use of sawmill residue and to reduction in pulpwood shipments to the Lake States. Plant receipts of pulping chips made from sawmill residues totaled 499,160 units for all plants that received chips from the two States.

Aerial Photo Interpretation

Training in the forestry application of photo interpretation techniques continues to be a prominent part of our program of photogrammetric research. Besides helping Region 4 in its annual photo training school, we held an interregional training school in Ogden for 20 foresters and engineers from nine Forest Service regions. This school was held at the request of the Timber Management Division of the Washington office.

An increasing number of foreign foresters and engineers is coming to Ogden for training in forest photogrammetry. During the year, 11 men from five countries were given this training.

The training handbook in forest photo interpretation published early this year was a major contribution to photo training methods. Requests for this handbook have been received from all over the world. A visiting Japanese delegation has asked and received permission to translate it for use in their country.

A training kit has been prepared containing the 13 photo problems described in the handbook, together with the aerial photos and photogrammetric tools and scales needed for solving them. Although the kit sells for $10 and has been available only since March, approximately 1,000 have been sold through the R-4 Division of Engineering.

Development and testing of aerial photo techniques for increasing the efficiency of land use studies continues as a major objective in our photo research. In 1960 we published aerial volume tables for ponderosa pine and completed collection of data for a new composite table for Rocky Mountain conifers.

FOREST ECONOMIC STUDIES

There are about 35 million acres of commercial forest in the Northern Rocky Mountain and Intermountain Regions. The tempo of logging has nearly doubled since World War II and will increase still more in years ahead. This prospect of continued heavy and rising demands for wood gives new and added significance to the matter of adequacy of timber-growing programs in these regions. As many foresters have observed, the time is already past when we can be satisfied merely to know that the forests which cloak the countryside are growing. The real question is whether they are growing fast enough to meet future needs and whether they are producing the kind of timber that will be demanded.

Inventory procedures and management planning in the past have not probed deeply into the matter of stand capabilities. In this Mountain State area, many stands are producing at only partial capacity because prolonged overcrowding has sapped their vigor. Growth losses from this factor alone are disastrously heavy in some forests. There are, of course, many vigorous, fast-growing stands in these regions, but many of these will likewise slow down unless steps are taken to prevent overcrowding.

Japanese foresters receiving training in forest photogrammetry.

This is only one facet of a complex management problem, but it is sufficient to underline the point that the second growth forest of the future will fall considerably short of producing expected timber yields unless the intensity of management is greatly increased.

For the past 3 years the economics study group has directed most of its attention to the problem of evaluating management alternatives, attacking it from four different directions.

1. We have collaborated with the Division of Forest Management Research in what might be termed a study of the potentialities of management. We have sought to determine just how much financial yields can be increased by thinning and pruning. The report of this study indicates that although current growing stock is not as good as has generally been thought, the forest land is potentially very productive if it is managed properly.
2. In collaboration with the Forest Survey section and the Division of Forest Management Research, the economics staff has tackled the basic problem of data limitations. The changing emphasis on forestry in these regions has made the traditional forest inventory data increasingly inadequate as a description of the timber resource. They do not describe the capacities of existing stands

to respond to treatment. Nor do they provide any firm basis for deciding what can and should be done to these stands or what the treatments will cost.

This is a fundamental weakness because no operation can advance beyond the information it has to work with. This station, therefore, has been working with other experiment stations and Forest Service regions in the development of data systems and procedures that will provide a better picture of the resource. This effort culminated in a field test of a multiple-plot system near St. Regis, Montana, in 1960 (see p. 27 above). The evidence to date indicates it is a forward step in the direction of better inventories.

3. The development of more descriptive statistics provides the basis for program evaluation in general terms but does not by itself solve the problem of dealing with management on the ground. In properties or management units that run into hundreds of thousands of acres, the task of describing and cataloging individual stand situations is both large and complex. Even so, it is considerably less difficult than the jigsaw puzzle task of fitting masses of information on stand conditions together to create the coherence essential for determining priorities and limits of justifiable action.

   This king-size task of developing inventory controls and effective interpretive procedures has long plagued management planners. They have experienced real difficulty in defining economic limitations and in establishing priorities of action. Our economics unit has therefore been collaborating with the Intermountain Region of the Forest Service for several years in a study of this problem in northern Utah. We are seeking to develop tools and guidelines that will aid management planners in their task.

4. The Forest Service has defined general timber production objectives for the various timber growing regions that seem compatible with long-range economic goals of the nation. However, in the Northern Rocky Mountain and Intermountain Regions, at least, the realism of these forestry objectives, considering the cost of achieving them, is still something to speculate about. For example, we do not have reliable answers to the following questions:

   △ How much effort will be needed to put the existing forest in more satisfactory shape for timber growing?

   △ What trends of output will result from different levels of management?

   △ What is a reasonable level of potential productivity?

   △ What values can be gained by intensified management?

   △ What program levels are economically justified on the national forests?

In an effort to shed more light on this subject, we have collaborated with Forest Management Research and the Northern Region of the Forest Service. We have analyzed the management problem in the 10-million-acre Clark Fork Unit of western Montana with particular reference to national forests. We have attempted to indicate the nature and size of the management task involved in that area, and the gains to be realized from management. Beyond that, we have attempted to establish some guidelines for deciding economic feasibility. The report of this study is now being prepared.

FOREST UTILIZATION RESEARCH

In past years much of the work of this division was devoted to keeping abreast of changes in the timber industry complex, promoting the use of research results, and encouraging sound industrial development. Work in all these important general fields has continued, but heavy emphasis is shifting toward more clearly defined projects. Within the four major fields of timber growth, timber harvesting, timber processing, and timber utilization our major research effort is following the "narrow and deep" guidelines; it is attempting to describe more adequately some fundamental relations that control timber utilization.

TIMBER GROWTH

Specific Gravity Determination

Specific gravity has been recognized for many years as a suitable criterion for evaluating many wood properties (*e.g.* strength, pulp yields, machinability, etc.), and if any single simple measure of a tree will reveal more about its properties than any other, gravity is that measure. Any forest includes many species, each with its own average specific gravity; and within each species a wide range of values is represented. Such variance may result from differences in site, range, elevation, latitude, climate, soils, genetic factors, or other variables. Much remains to be learned about what causes differences in specific gravity between species or among trees of any one species.

Techniques have been developed that enable rapid determination of specific gravity at breast height from standard calibrated increment cores. Systematic sampling of specific gravity of *all* the western softwoods is now under way as part of the Forest Survey. This information will be invaluable. At present rates of measurement, results will be relatively slow, but when this task is completed we will have a complete survey of the range of gravities for all the western species throughout each species' range.

We need to know more than specific gravity at breast height. Since gravities diminish upward in each tree, we need to correlate breast height values with *total* tree gravities. This work is now under way in a series of projects being conducted cooperatively by the Forest Products Laboratory and our Missoula, Spokane, and Bozeman research units. Field data have been collected by the Forest Products Laboratory for Douglas-fir, and by Intermountain Station for grand fir and western larch. Measurements for lodgepole pine are next on the schedule, and additional species will be studied as soon as possible.

The technique for determining tree gravities involves selection of disks or small cross sections at uniformly spaced intervals along the stem. Gravities of each disk are determined and, based on the proportionate volume represented, averaged to give a total value for the tree.

Spiral Grain Studies

Other properties besides specific gravity play an important role in determining tree quality. Spiral grain is one of these, and is especially important for trees used for transmission poles. We reported last year the start of field work designed to sample the frequency and severity of spiral grain in western larch, and the conditions under which it occurs. This field work is now completed after measurements of 366 plots in Montana, Idaho, and Washington. Information gathered on each plot will relate stand and site conditions to individual tree properties including those quality factors considered important for commercial pole utilization.

The study of performance of spiral grained poles is nearly concluded. Analysis of the tendency to twist after installation indicates that left-hand spiral poles deflect more than right-hand poles regardless of species, treatment, moisture content, or special handling. A joint study with the Forest Products Laboratory will evaluate the strength properties of excessively spiraled poles.

TIMBER HARVESTING

The problems attendant on logging the more difficult forest types and terrains are easily divided into three broad areas: economic, mechanical, and certain forestry factors such as soil, silviculture, game habitat, disease, and insects.

This year we began studies evaluating economic factors in two types of cable logging: conventional high lead, and a prototype remote controlled carriage suspended by skyline. These studies were conducted jointly with National Forest Administration on the Boise and Payette National Forests. First-year results were inconclusive, but apparently both systems can yard logs from extremely steep slopes at economically feasible costs.

One objection to previous overhead cable experiments in the Rocky Mountain types was low total daily output. This limitation seems to have been overcome on both units studied, as their production ranged from 40 to 60 M bd. ft. per day when crews and equipment were operating smoothly.

Qualitative determinations have not yet been made, but examination of cut-over units indicates minimal soil disturbance. If supporting road systems prove to be fully acceptable and economic, cable logging may solve many problems of logging steep areas.

TIMBER PROCESSING

Markets for lumber and plywood were generally poor during most of 1960. Even though many sawmills had to curtail lumber production, the industry continued to back its faith in the future by investing heavily in new and improved manufacturing facilities. One new plywood plant was established at Missoula, and an older plywood mill at Polson, Montana, was modernized and enlarged. Several additional plywood mills have been proposed. Construction of one of these is scheduled to start early in 1961. The newer mills either are using or propose to use large quantities of western larch, a species whose merits are finally being recognized.

The Waldorf-Hoerner Company pulp mill at Missoula has completed installation of a kraft paper and liner board machine and is now adding a bleaching plant. Management is contemplating additional changes and improvements.

Modern high speed sawmills are also being erected in several locations. These mills are designed for specialized production of such items as studs and rafters, and provide a valuable addition to the industrial base of the region because they will use logs too small for regular sawmills.

TIMBER UTILIZATION

Ways and means of publicizing more efficient uses of wood products always present a challenge. One such opportunity is to encourage use of wholly new design features.

Hyperbolic paraboloid wood shell roofs provide high strength at relatively low cost because they can use low-grade material. A scale model of such a roof constructed at the station has been displayed to several architects. Reactions generally were quite favorable, but no full size shells have yet been constructed in this region. Additional models, even full scale, probably need to be built and given wider display.

RANGE MANAGEMENT RESEARCH

WILDLIFE HABITAT MANAGEMENT

Timber-Wildlife Relations in Northern Idaho Forests

Seral understory vegetation in the forest climax zones of northern Idaho is of interest not only to foresters concerned with tree regeneration but to big-game managers as well. The large herds of deer and elk in northern Idaho depend heavily upon browse produced in plant communities that develop successively when timber stands are opened up or removed by logging or fire. A study of the structure of these seral shrub communities in the broad cedar-hemlock zone of northern Idaho has been under way for the past 3 years. Information obtained from this study should provide background for managing big-game habitat in this area.

Shrubs growing in the cedar-hemlock zone fall into three distinct growth-form layers. The "tall shrubs" can grow to 20 or 30 feet high, and their crowns may soon grow above reach of game. "Intermediate" species seldom exceed a height of 7 feet, and "low shrubs" 3 feet, and thus tend to remain available to game. All three layers are commonly present in the same stand.

Two of the most important factors influencing the species and amounts of shrubs present in any timber stand have been found to be: (1) type of past disturbance and (2) amount of tree overstory. The accompany graph (p. 34) shows the influence of these two factors on major individual species and the total shrub cover. The data are averages from 83 areas sampled throughout northern Idaho. Each canopy class included 13 to 35 sample areas; each treatment class 8 to 46 areas.

Broadcast burning particularly favors Scouler willow, redstem ceanothus, snowbrush ceanothus, Sitka alder, and bitter cherry. Scouler willow and redstem ceanothus, along with Saskatoon serviceberry and myrtle pachistima, are the most desirable browse for big-game.[7]

Certain shrub species persist even under fairly heavy shade; others progressively decrease in amount as shading by trees increases. Unfortunately, most of the desirable browse species are of the latter type.

Fourteen additional environmental factors also have been evaluated in relation to shrubby and herbaceous species. The full results will be reported in a publication now in preparation.

Management of Deer Forage on Summer Range

Three forbs that are important forage plants for deer as well as livestock on summer range were clipped for 10 successive years on the Wasatch Plateau in central Utah to investigate acceptable intensities of utilization. The species were Richardson geranium (*Geranium richardsoni*), Porter ligusticum (*Ligusticum porteri*), and edible valerian (*Valeriana edulis*). Plants from which 50, 75, or 90 percent of the total growth was removed each year at the flowering stage were compared with unclipped check plants.

As the accompanying graph shows, herbage production was depressed somewhat by the lightest clipping rate. This was especially true for geranium. Seed stalk production, which is often considered an indicator of plant vigor, was likewise reduced by light clipping. Seventy-five and ninety percent herbage removal had proportionately greater effects. However, it is of considerable interest to note that, even under the most severe clipping, productivity persisted at relatively high levels for about 2 years. This has pertinent implications for grazing management of livestock.

Evidently 50-percent herbage removal year after year represents at least the maximum intensity of use compatible with sustained productivity of these species. However, there appear to be good possibilities that grazing practices involving rest or rotational use may avoid the ill effects of close utilization by livestock.

Winter Game Range Improvement

Preliminary results of experiments in artificial pruning indicate that this may be a practical means of increasing deer browse from old, decadent bitterbrush plants. Stands of such

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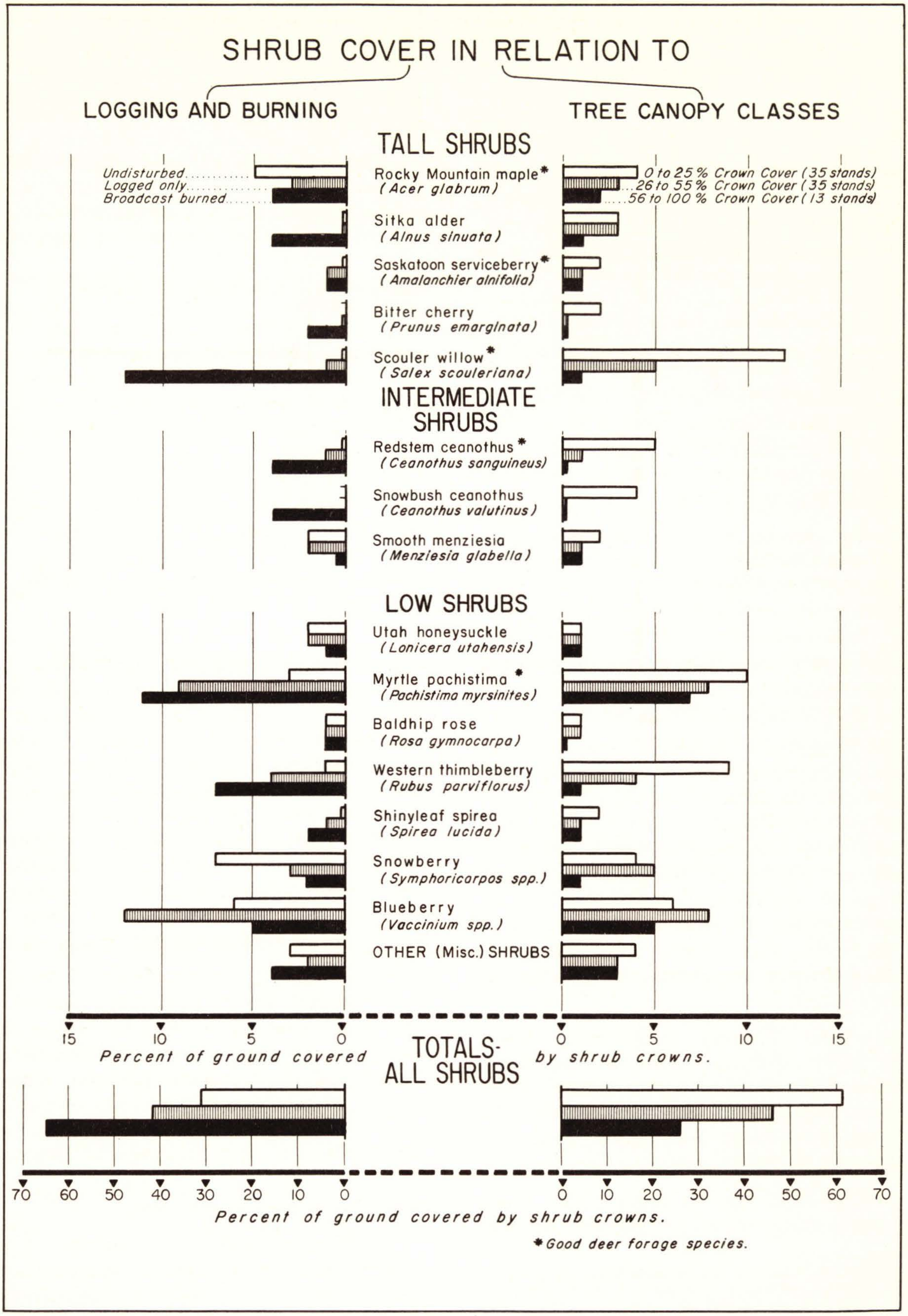
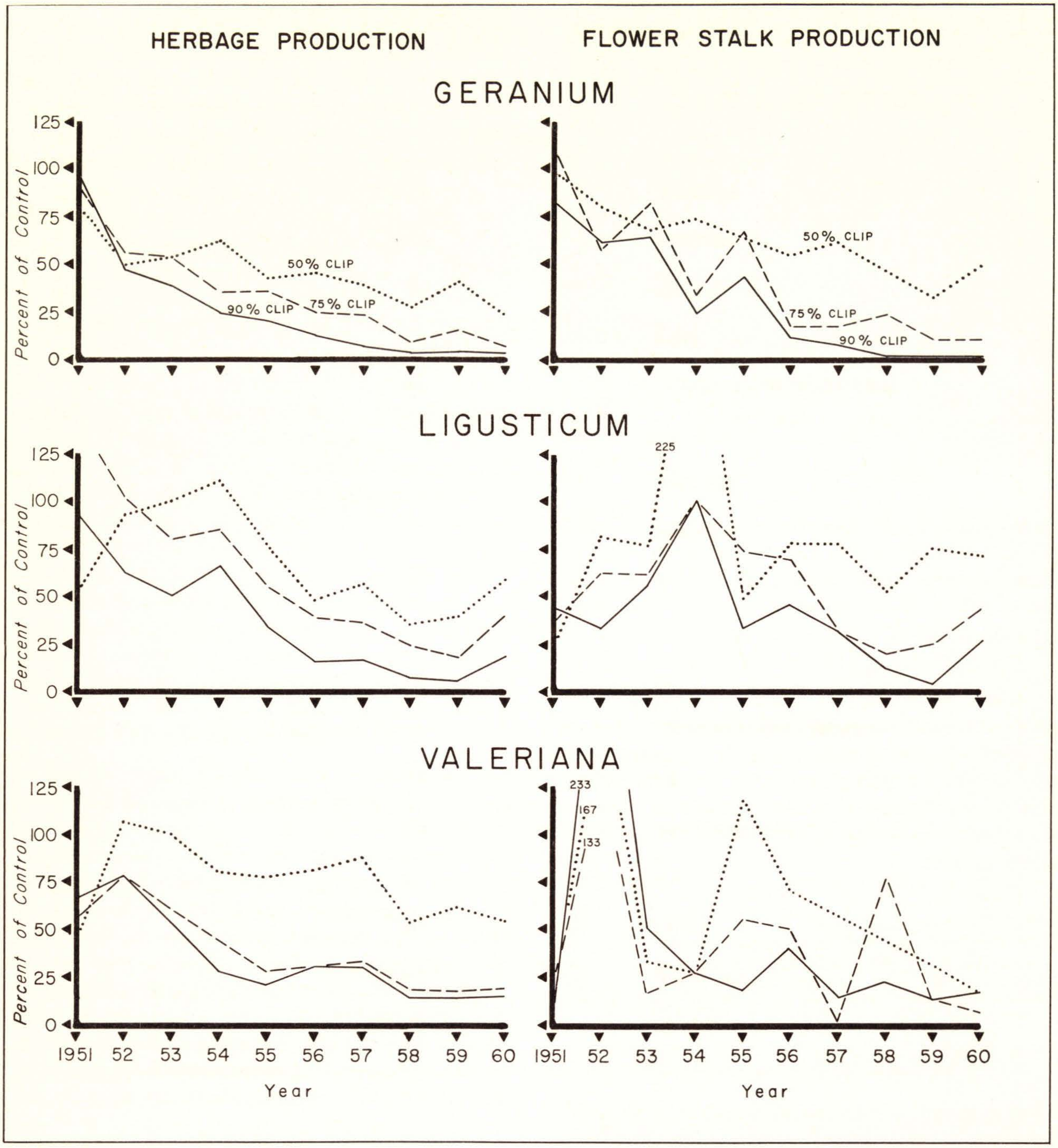
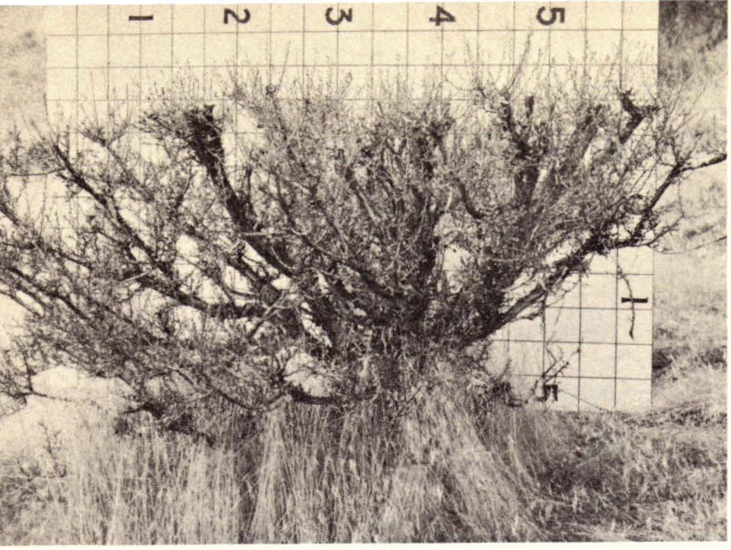
[7] J. E. Woolfolk, 1953. Some observations on a white-tailed deer winter range in Idaho. U.S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Res. Note 116.


SHRUB COVER IN RELATION TO
LOGGING AND BURNING
TREE CANOPY CLASSES
TALL SHRUBS
Undisturbed
Logged only
Broadcast burned
0 to 25 % Crown Cover (35 stands)
26 to 55 % Crown Cover (35 stands)
56 to 100 % Crown Cover (13 stands)
Rocky Mountain maple*
(Acer glabrum)
Sitka alder
(Alnus sinuata)
Saskatoon serviceberry*
(Amalanchier alnifolia)
Bitter cherry
(Prunus emarginata)
Scouler willow*
(Salex scouleriana)
INTERMEDIATE SHRUBS
Redstem ceanothus*
(Ceanothus sanguineus)
Snowbush ceanothus
(Ceanothus valutinus)
Smooth menziesia
(Menziesia glabella)
LOW SHRUBS
Utah honeysuckle
(Lonicera utahensis)
Myrtle pachistima*
(Pachistima myrsinites)
Baldhip rose
(Rosa gymnocarpa)
Western thimbleberry
(Rubus parviflorus)
Shinyleaf spirea
(Spirea lucida)
Snowberry
(Symphoricarpos spp.)
Blueberry
(Vaccinium spp.)
OTHER (Misc.) SHRUBS
15
10
5
0
0
5
10
15
Percent of ground covered by shrub crowns.
TOTALS-ALL SHRUBS
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
Percent of ground covered by shrub crowns.
*Good deer forage species.


HERBAGE PRODUCTION
FLOWER STALK PRODUCTION
GERANIUM
LIGUSTICUM
VALERIANA
Percent of Control
125
100
75
50
25
0
50% CLIP
75% CLIP
90% CLIP
225
233
167
133
1951
52
53
54
55
56
57
58
59
60
Year



Typical response to pruning of decadent bitterbrush plants. Twigs average approximately 6 inches in length, and most of the new growth is readily available to deer.

plants frequently encountered in southern Idaho produce little available browse for game animals. Heavy pruning that removed all canopy portions above 3 feet from the ground in such a stand gave an eightfold increase in twig production in the first year of an exploratory study.

Samples from two sets of 15 plants each showed no difference in twig production before pruning. At the end of the growing season following pruning, samples showed 1,863 inches of twig production on unpruned plants in contrast to 16,441 inches on pruned plants—an increase of 780 percent.

Spring deferment and heavy fall grazing increased the grasses and forbs and decreased the sagebrush in the range on the right. Both areas were in poor condition in 1950. The area on the left has been spring grazed. Neither area had been grazed when photographed in 1958.

MANAGEMENT OF SPRING-FALL SHEEP RANGE

Heavy fall grazing has been as effective as complete protection for improving deteriorated sagebrush-grass range at the U. S. Sheep Experiment Station near Dubois, Idaho. Herbage production under heavy fall grazing was compared with that under no grazing from 1950 to 1960 on range previously spring-grazed and in poor condition. Over the 10-year period relative grass production increased and sagebrush decreased similarly in both areas, as shown by the following tabulation:

Treatment and class of forage	Percentage of total production		
	1950	1953	1960
Total protection			
Grass	25	28	40
Forbs	10	9	11
Shrubs	65	63	49
Fall grazed			
Grass	29	32	45
Forbs	11	8	10
Shrubs	60	60	45

Likewise, productivity of range already in good condition was maintained as effectively by heavy fall grazing as by complete protection in other phases of the study. Spring grazing, however, reduced grasses and forbs and increased shrubs — primarily sagebrush. This favorable reaction of sagebrush-grass range to heavy fall sheep grazing is probably accounted for by (1) damage to the green shrubs by utilization in the fall while grasses and forbs, essentially dormant at that season, are not damaged by use; and (2) increased vigor of grasses and forbs resulting from deferment of grazing until maturity.

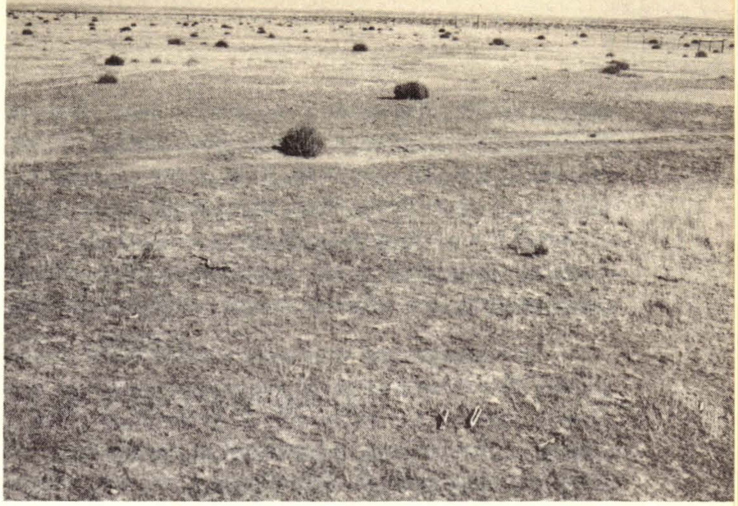
These results demonstrate the advantage of rotating spring and fall grazing for improving or maintaining the condition of sagebrush-grass range.

Cheatgrass Range Management

Widespread die-off of cheatgrass observed in southern Idaho in 1960 emphasizes one of the problems and hazards of a grazing enterprise based on annual-type range. Characterized as winterkilling, the phenomenon was attributed to unusual weather early in 1960—weather that resulted in one of the poorest grazing years on record for spring-fall ranges dominated by cheatgrass. We have found no reference to this kind of die-off in the literature, although extreme variability in productivity is characteristic of cheatgrass range.

Following rains in the preceding October, cheatgrass seed sprouted and produced excellent stands with as much as 3 inches of fall growth. Observations indicated that the crop was still alive February 1. But subsequently much of it apparently was killed by severe and unusual weather conditions in late winter or early spring. The winterkilling was most pronounced on south slopes, but it was also prevalent on bottom sites. On gently undulating to flat uplands in our experimental ranges the winterkilling occurred in irregular patches (see illustration). Yield of cheatgrass that survived was much below normal. Within 3 weeks of maturity, when cheatgrass loses most of its grazing value, few plants had made more than 3 inches' height growth. Consequently, range livestock were heavily dependent, especially in spring, on remnants of the perennial grass stands that formerly dominated present cheatgrass ranges—remnants that commonly are exceedingly sparse.

The critical situation on these ranges this year is illustrated by data from the first year of grazing studies at the Saylor Creek Experimental Range near Glenns Ferry, Idaho. Cheatgrass range provided an average of only 3.6 days' grazing per acre per head of yearling steers from April through September where perennials were very sparse, and 4.7 days per acre where such perennials as needlegrass (*Stipa* sp.) were prominent. Comparable values for sheep were 13 and 20 sheep days per acre during the period April 12 to May 5. Intensive grazing studies are under way to determine how to use cheatgrass range most efficiently, and also how best to encourage conversion to perennials. Facilities at the Saylor Creek Experimental Range will be completed during 1961 to provide an outdoor laboratory for the research program on cheatgrass range.



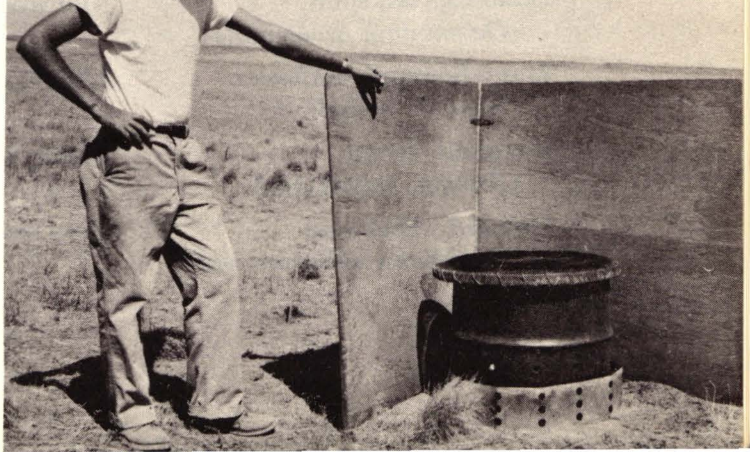
Winterkill of cheatgrass in irregular patches at the Saylor Creek Experimental Range shows as dark areas in this photo taken in September 1960 when surviving cheatgrass had matured and scattered Russian thistles were about full grown. The main perennial in the foreground is a small bluegrass, *Poa secunda*. Perennials did not winterkill.

Equipment for Fire Treatment

A technique and apparatus devised this year at the Boise Research Center permit safe experimental burning of range vegetation even under conditions of high fire hazard. They were developed in connection with studying influences of fire on important grass species of sagebrush-grass ranges in southern Idaho.

A 55-gallon oil drum, cut down to two-thirds its original size and with both ends removed, was the main component. Placed over an individual plant, this drum contained the fire and concentrated the desired amount of heat. Perforations near the bottom of the drum admit necessary air, and removable 1/4-inch mesh screen over the top controls sparks. An additional larger ring of sheet metal about 6 inches high surrounding the base of the drum prevents spread of fire when study objectives dictate removal of the drum before the fire is

Equipment developed for safely studying effects of fire on important range species.



completely extinguished. A 4- by 8-foot sheet of 3/8-inch plywood, cut and hinged in the center, provided an effective windbreak for controlling wind velocity. Prescribed temperatures were achieved by adding supplementary uniform fuel, such as shredded paper, specific amounts being calibrated through use of inexpensive pyrometers.

The equipment was used successfully in applying fire treatments of varied intensity at different seasons to hundreds of individual plants. We plan to develop this technique further for increased versatility and efficiency.

STUDIES ON SUMMER RANGE

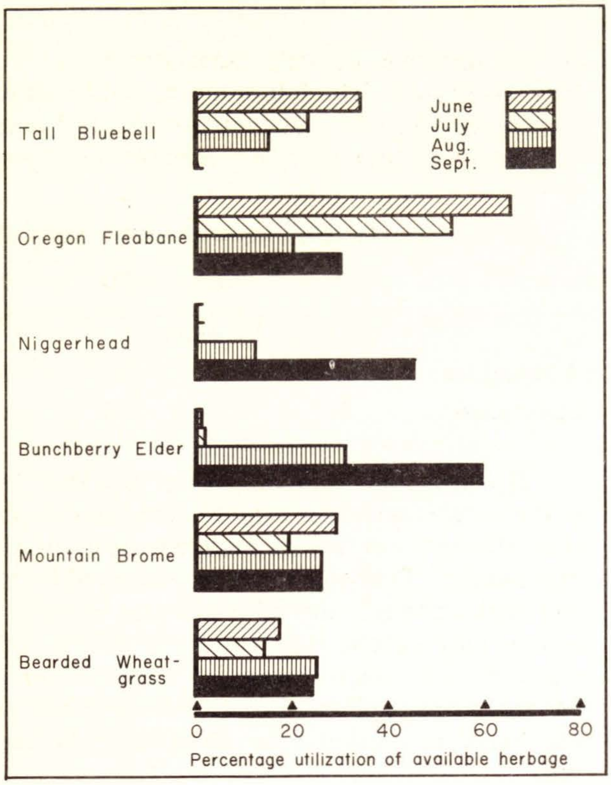
Utilization of Forage by Sheep on Aspen Summer Range

Utilization of the various forage species varied considerably by months during the first season of a study of sheep grazing management on the aspen zone of central Utah. A group of the most succulent forbs was utilized heavily in June but, as they matured and became dry, utilization declined. This group included tall bluebell (*Mertensia leonardi*), cowparsnip (*Heracleum lanatum*), white polemonium (*Polemonium albiflorum*),and Oregon fleabane (*Erigeron speciosus*). Utilization of American vetch (*Vicia americana*), butterweed groundsel (*Senecio serra*), niggerhead (*Rudbeckia occidentalis*), and of shrubs—snowberry (*Symphoricarpos* spp.), bunchberry elder (*Sambucus microbotrys*), and aspen sprouts (*Populus tremuloides*)—increased in August and September. In fact, most of the shrub species were not utilized much until August and September, when most of the forbs had matured and become dry. Grasses, especially bearded wheatgrass and mountain brome, were utilized lightly throughout the grazing season. Use of most grass species increased slightly as the succulent forbs began to dry in July and August.

The 1960 summer grazing season was exceptionally dry. Practically no rain fell between June 15 and August 15, and only two light storms occurred during August and September. Forage dried early, and by August 15 only the shrubs and a few of the grass species, especially those growing under aspen, remained green. Because the feed was so dry during the latter part of the grazing season, sheep were restless. They moved back and forth over the range and trampled considerable feed into the ground.

Utilization varied not only in amount but also in the portions of the plants selected. This is shown by the following tabulation of descriptive records taken in the latter part of August:

Species	*Parts eaten*
Bunchberry elder (*Sambucus microbotrys*)	All leaves within reach of sheep and a few terminal twigs.
Snowberry (*Symphoricarpos* spp.)	50 to 60 percent of leaves—no twigs.
Quaking aspen (*Populus tremuloides*)	60 to 70 percent of leaves within reach of sheep.
Tall bluebell (*Mertensia leonardi*)	A few of the bottom leaves that were still partly green.
Butterweed groundsel (*Senecio serra*)	All leaves taken; flower head left.
Duncecap larkspur (*Delphinium occidentale*)	All leaves and flower panicles.
Many-flowered sunflower (*Viguiera multiflora*)	Most flower heads and some leaves.
Mountain brome (*Bromus polyanthus*)	Mostly seed stalks and tops of stems.
Bearded wheatgrass (*Agropyron subsecundum*)	Very little use; few leaves and stems.



Herbage yields this year varied from about 300 to 1,100 pounds (air dry) per acre, depending on range condition and site factors. Tall bluebell, white polemonium, butterweed groundsel, niggerhead, bunchberry elder, bearded wheatgrass, and mountain brome were some of the most productive species.

These studies on deteriorated, high-elevation, aspen range on the Mud Creek Allotment of the Uinta National Forest were started in 1959. Past overstocking was reduced 66 percent in 1953, and the range is recovering under a relatively light stocking rate averaging 7 sheep days per acre (ewes with lambs). Determining effects of utilization at different times during the grazing season, which extends from June 15 through September, is one phase of studies to determine how to get maximum improvement under grazing.

Pocket Gopher-Range Relations

A sharp reduction in 1960 pocket gopher signs was very noticeable on mountain summer range on study areas at Monte Cristo on the Cache National Forest and at Mud Creek on the Uinta National Forest.

Counts of gopher mounds on permanently marked study plots at Monte Cristo showed only one-fourth as many mounds in 1960 as the average of the preceding 3 years on open herblands. For the aspen type, the 1960 mound count was less than half the average of the previous 3 years. This supports observations indicating that the die-off was greater in open types than under aspen. General observations at Mud Creek indicate similar reductions in gopher numbers in 1960 on the Uinta Forest. This is the first appreciable die-off of gophers at Monte Cristo since records were started in 1951.

Counts of gopher mounds per acre on the Monte Cristo study area during the past four seasons were:

	1957	1958	1959	3-year average	1960
Open herbland	1,693	1,730	1,503	1,642	410
Aspen-covered areas	1,333	1,593	1,127	1,351	613

WATERSHED MANAGEMENT RESEARCH

Management of forest and range lands in the Intermountain area is essentially a problem in managing steep slopes. The ultimate goal is to manage each parcel of land so that optimum current production is achieved while the land is maintained or restored to a productive condition for the future. Water, forage, timber, wildlife, recreation, and minerals constitute the important resources that are constantly utilized. Their utilization poses problems in watershed management. On areas where soil, plant cover, and climate are in balance, we strive to maintain that equilibrium by developing methods for utilizing these resources without damaging the ground cover. Where watersheds are already damaged, the development of efficient rehabilitation methods is another goal. Finally, we seek to improve the amount, quality, and timing of delivery of water yields consistent with other operational activities to insure continued supplies of water. These are the objectives of research in watershed management.

This report summarizes recent accomplishments by this division in establishing relations between land use practices, soil stability, and flood control.

REQUIREMENTS OF RANGE WATERSHED PROTECTION

Several years ago, research developed watershed protection criteria for mountainous range watersheds on steep slopes in southern Idaho. Here an inherently unstable soil derived from granite, and damage from excessive grazing, jointly create a difficult problem in erosion control. Two specific ground cover conditions were shown to be necessary to prevent overland flow and soil erosion from wheatgrass and cheatgrass-annual weed range sites. These conditions were: (1) that no less than 70 percent of the soil surface be covered with vegetation or litter, and (2) that bare openings between plants and patches of litter be no larger than 4 inches in diameter on wheatgrass sites and 2 inches on cheatgrass sites.

These conditions effectively controlled overland flow and soil erosion during a 30-minute rainstorm at a constant rate of about 3.7 inches per hour applied with a rainfall-simulating infiltrometer. This study also established the relation between ground cover densities and sizes of bare openings actually associated on sites of these two types. The following tabulation shows the average maximum diameter of bare soil openings found at four different densities of ground cover:

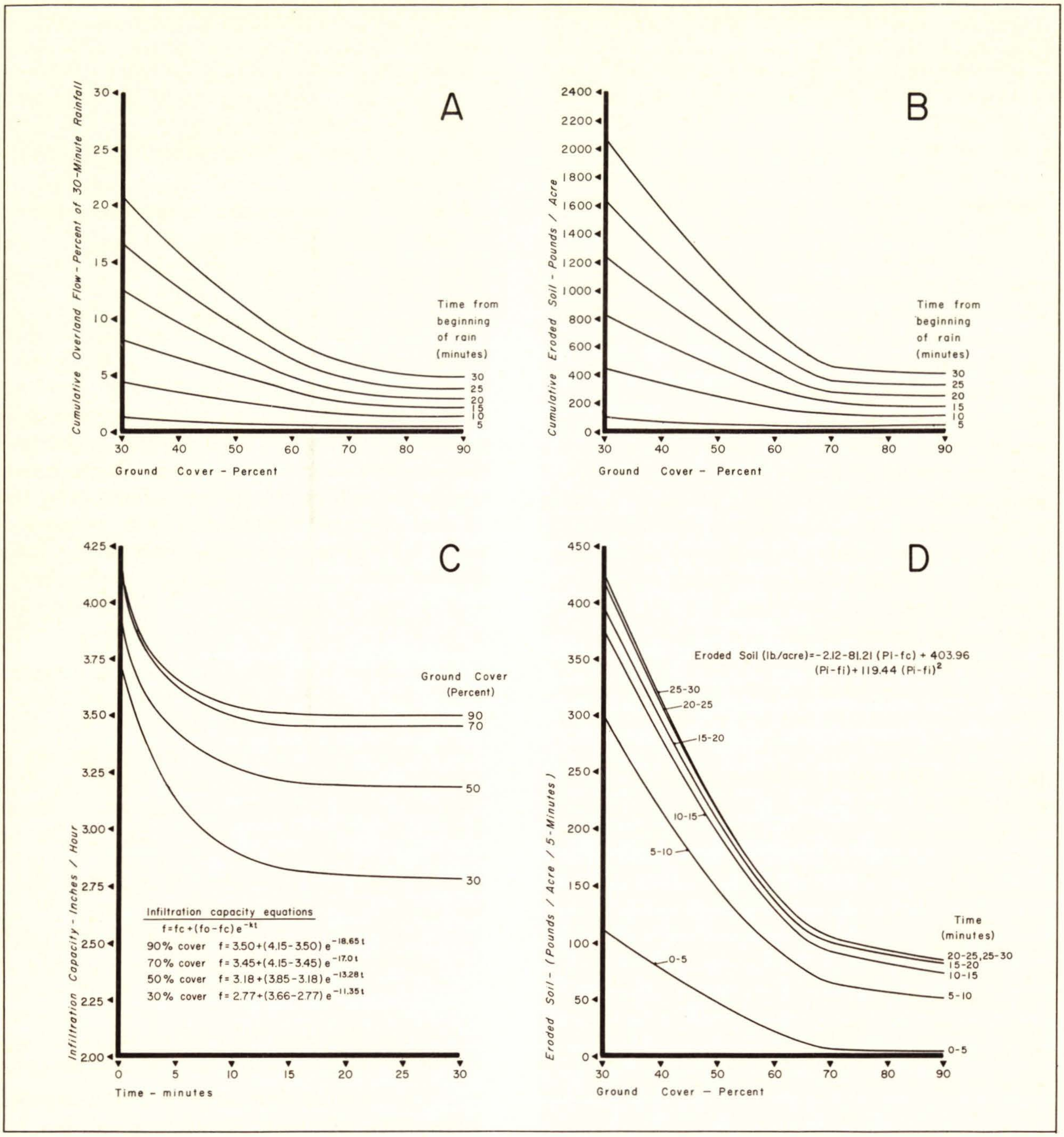
Cover type	Ground cover density (percent)			
	90	70	50	30
	Inches			
Wheatgrass	4	4	11	25
Cheatgrass	2	2	8	13

Recently the question arose whether less stringent ground cover requirements might provide effective control of summer storm runoff and erosion. This question was prompted by the fact that although rainfall intensities of summer storms may exceed that employed in the infiltrometer tests, such intensities normally persist for only brief periods (5 to 10 minutes) and are not likely to continue for 30 consecutive minutes.

An answer to this question was obtained by additional analyses of data from the Idaho study for the years 1947, 1948, and 1951. These analyses were made for each of the six 5-minute periods of the 30-minute test rainstorms to determine:

1. The relation of overland flow and soil erosion to ground cover and bare opening conditions during each 5-minute period, on both wheatgrass and cheatgrass-annual weed sites.
2. The inherent infiltration capacity characteristics of soils having different ground cover and bare opening conditions on both cover types expressed on a time basis from zero to 30 minutes.
3. The relations of soil erosion to overland flow expressed in terms of the infiltration characteristics under different ground cover and bare opening conditions.

A series of equations relating overland flow and erosion to ground cover and bare opening values was developed. These relations all have a common characteristic: they reveal that, regardless of which 5-minute period is being considered, the amounts of overland flow and eroded



A. Cumulative overland flow; *B*. Cumulative soil erosion; *C*. Infiltration capacity; *D*. Soil erosion from wheatgrass range sites on soil derived from granite for different ground cover densities by 5-minute periods. These results were obtained by simulating rainfall for 30 minutes at a constant rate of 3.74 inches per hour (Boise National Forest, 1947, 1948, 1951).

soil increase only slightly as the ground cover decreases from 90 to 70 percent density; but both accelerate rapidly as the area of ground surface covered by plants and litter falls below a density of 70 percent (see A and B of graph, p. 41).

Utilizing the equations expressing overland flow in terms of ground cover and bare opening conditions, together with the 5-minute records of precipitation on each study site, Horton's standard infiltration capacity equations were determined for the associated ground cover and bare opening conditions shown in the tabulation above. These equations and the infiltration capacity curves representing them are shown for wheatgrass sites in C of the accompanying graph. They explain why overland flow from a rainstorm becomes damaging as ground cover is reduced below a density of 70 percent. As long as the rainfall rate is less than the infiltration capacities shown by these curves, no overland flow develops. But when rainfall intensities exceed the infiltration capacities, overland flow, equal to that precipitation in excess of the infiltration values, will occur. The amounts of overland flow from sites having infiltration characteristics of the 70 and 90 percent ground cover conditions will vary but slightly. Conversely, overland flow from sites having only 50 or 30 percent ground cover will be substantially greater because their infiltration capacities are smaller.

Each ground cover condition shown in C above has its own characteristic infiltration capacity curve. One characteristic peculiar to each curve is its final (f_c) or minimum infiltration capacity. Therefore, for any rainfall rate (p_i) occurring over any time interval, the term p_i-f_c expresses and defines ground cover conditions in terms of a constant terminal rate of overland flow. Also, the amount of overland flow during any interval of time depends upon the rainfall rate (p_i) and the infiltration capacity (f_i) during that time interval. The rate of overland flow, therefore, is expressed by the term, p_i-f_i.

Equations expressing soil erosion in terms of p_i-f_c and p_i-f_i were developed to relate soil erosion to overland flow for each of the ground cover density and bare opening conditions shown in the tabulation above. These equations are applicable to any summer rainfall intensity not exceeding 30 minutes' duration. They provide a means for estimating amounts of soil that can be expected to erode from wheatgrass sites when only the rainfall intensity pattern of a storm and the ground cover conditions are known. The equations, in combination with the infiltration capacity equations in graph C, were used to compute the amounts of eroded soil produced during each of the six 5-minute periods comprising the 30-minute test rainstorms employed in these studies. The relations of these amounts to ground cover conditions are shown in graph D.

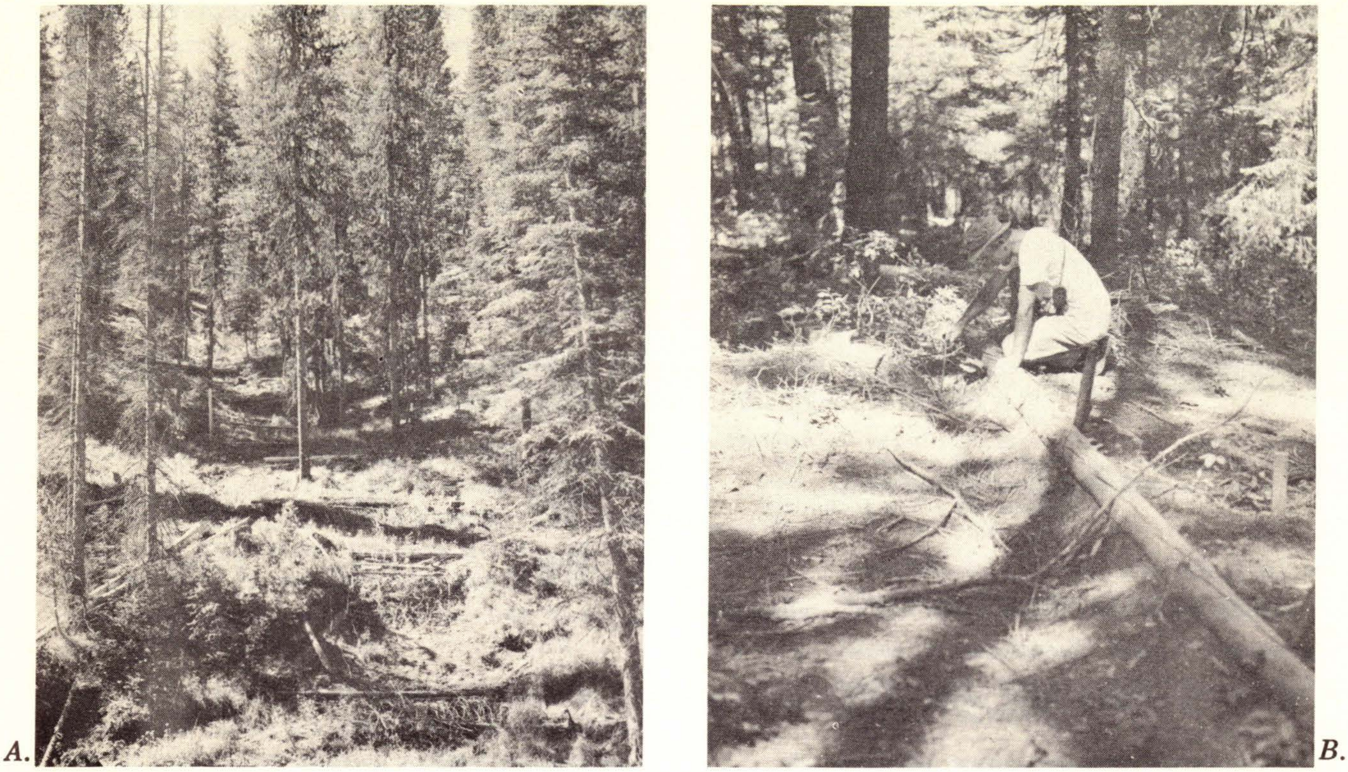
Again, the curves in D show that, regardless of which 5-minute period of a rainstorm is involved, the amounts of soil eroded accelerate rapidly only when the ground cover is reduced to a density of less than 70 percent. This relation is especially noteworthy in the zero to 5-minute period, which had not been influenced by any previous rainfall or runoff. Curves developed for cheatgrass sites are similar to those presented above.

The technical evidence resulting from these analyses supports the conclusion that, within each of these two range types under consideration, the ground cover conditions required to prevent accelerated storm runoff and erosion remain essentially the same, irrespective of the duration of the high-intensity burst or of the time at which it occurs in the storm. The evidence also strengthens the validity of the protection requirements for these sites as stated several years ago and indicates that there are no less stringent ground cover and bare opening conditions capable of preventing accelerated overland flow and soil erosion from these sites.

LOGGING ROAD AND SKIDTRAIL STABILIZATION

Two recently completed field studies provide information useful in controlling erosion from logging roads and skidtrails.

The objective of one study was to determine the effectiveness of different types of structures in controlling soil erosion from skidtrails. The skidtrails, variable in steepness, were located on sidehills and in ravines on soils derived from granite or basalt. The control structures were either log water-bars or slash dams built at various predetermined spacings, depending upon skidtrail gradient (see follow-



A. Check dams constructed of slash at 10-foot intervals in a skidtrail located on a 60-percent slope. No visible erosion is occurring. *B.* Log water-bar structure on logging road on about a 20-percent slope. Very little soil eroded from this road.

ing figure). Some skidtrails were treated by scattering lopped slash on the surface. All skidtrails were reseeded to grass after the structures were installed.

Each year for 4 years following installation of the structures, quantitative measurements were made of sediment movement down the trails. A final qualitative evaluation was made of the effectiveness of the various structures and their spacing. Conclusions drawn from this study were that on moderate 20- to 30-percent slopes, maximum spacing of structures should not exceed 70 feet; while on steeper 40- to 70-percent slopes, the maximum spacing should not exceed 40 feet. Structures should be spaced more closely in ravines than on sidehills. Wider intervals between structures for similar slope gradients may be allowed on soil derived from basalt because it is generally less susceptible to erosion than soil derived from granite.

The second study dealt with effects of mechanical treatments on the establishment of grass cover on raw logging road surfaces. Seeding to grass in conjunction with diagonal cross-ditching is standard practice for controlling erosion and sediment flows from logging haul roads on timber sale areas. This study disclosed that on granitic soils of southwestern Idaho hand broadcasting of seed followed by harrowing, hand broadcasting followed by scarifying to a depth of 12 inches, and scarifying followed by hand broadcasting seed do not result in significantly better stands of grass than does hand broadcasting of seed without seedbed preparation. Fertilizing at time of seeding with 200 lbs. per acre of a commercial 20-20-0 fertilizer did not significantly improve establisment of the grasses.

Results of these two studies indicate that postlogging treatments such as these, consisting of mechanical structures and seeding on roads and skidtrails, may effectively control overland flow and erosion.

WINTER FLOOD CONTROL MEASURES UNDER STUDY

On an east Sierra Nevada mountain watershed, a new project has been started to determine the influence of forest cover and soil condition as they influence behavior of rain-on-snow floods. Objectives of this research are: (1) to study the physical effects that forest floor conditions have on soil freezing and on the metamorphism of an early-season snowpack; and then by simulating a winter rainstorm (2) to determine the hydrologic effects of the snowpack and forest floor condition on water intake, overland flow, and soil displacement. This information is especially needed for the cobbly loamy soils derived from andesite that cover a large portion of the Truckee River basin.

For this study, six pairs of plots were selected to represent a range of natural forest floor conditions (see following table) found under a young Jeffrey pine stand established after an earlier era of destructive logging and grazing. One of the floor conditions was modified by superimposing shallow furrows along the slope contour.

Overland flow and soil displacement on six types of forest floor under young Jeffrey pine produced by a simulated long-duration low-intensity rainstorm

Forest floor condition	Simulated storm	Overland flow	Soil displacement
	Inches	*Percent*	*Tons/sq. mi.*
Sparse grass-pine litter cover (21%), abundant exposed rock (23%)	5.8	38	1,012
Sparse grass-pine litter cover (18%), some exposed rock (6%)	4.8	27	191
Pine litter-duff (3 inches deep) burned by wildfire, recovered with freshly fallen needles (1 inch deep), no exposed rock	5.2	4	23
Pine litter-duff (3 inches deep) burned, no exposed rock	5.8	3	84
Sparse grass-pine litter cover (9%), abundant exposed rock (22%), contour furrows (2.5 feet apart)	5.9	2	214
Dense grass-bitterbrush-pine litter cover (85%), very little exposed rock (2%)	[1]5.0	0.2	14

[1] Single runoff plot.

Before the wintertime phases could be investigated, it was necessary to determine the inherent infiltration-runoff characteristics of the plots subjected to a maximum winter rainfall rate under conditions not confounded by freezing temperatures and the presence of snow. Therefore, early last fall our technicians applied artificial rain with a modified type-F infiltrometer to the plots at an average rate of about 0.6 inch per hour for 8 to 10 hours. This rate exceeds the maximum of 0.5 inch per hour recorded during the severe winter flood in 1950.

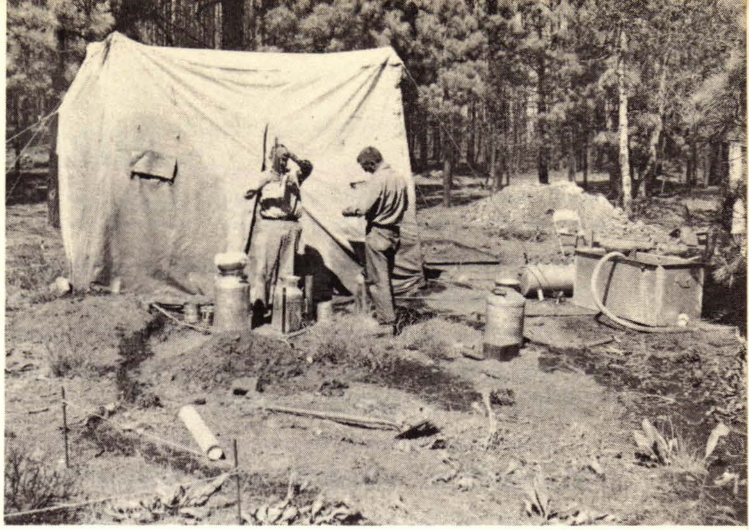
Results from those tests show how the six forest floor conditions ranked in order of decreasing overland flow (see above table). Overland movement of water varied from a high 38 percent on the sparsely covered sites containing much exposed rock but not contour furrowed to a mere trace of runoff from one bitterbrush and native grass plot with excellent coverage of plant litter. Where contour furrows were used on the deteriorated, rocky sites, they trapped overland flow and eroded soil, but the amount of runoff and displaced soil measured in the catchment trough does not indicate it. Actually this material was moved directly by raindrop splash from an exposed face of the furrow into the trough immediately below the furrow. On an unrestricted slope the next furrow downslope would act as barrier.

In view of the absence of protective ground cover, the relatively low runoff from the plots covered by deep pine litter that were burned by wildfire 3 weeks prior to applying rainfall was surprising. Apparently the good water-intake qualities that accrued under pine litter after years of protection were undamaged by burning and remained good during a long-duration low-intensity artificial storm. Supplemental protection from a thick covering of freshly fallen pine needles does not change water intake significantly. However, a covering of needles considerably lessens raindrop splash and, hence, reduces soil and ash displacement. The results thus far emphasize the importance of good ground cover in reducing overland flow and also encourage the use of contour furrows to supplement ground cover.

This winter when snow accumulates over the runoff plots left intact and after subfreezing temperatures prevail, vertical extensions of boundaries will be placed on the plots. Simulated rain will then be applied at the same rate (about 0.6 inch per hour) for 20 hours.

Afterwards we hope to be able to answer these important questions:

1. Will the presence of a shallow snowpack facilitate or hinder water intake?
2. What influence does frozen soil have on infiltration, and will this effect persist after a long period of steady rain?
3. Does the presence of forest floor plants, litter, and rocks modify soil freezing and the snowpack?
4. Do the water-retaining advantages of using manmade structures like contour furrows remain high during a rain-on-snow event?



Watershed technicians measuring and recording overland flow from a forest floor plot undergoing a simulated rainstorm inside the windbreaker tent of a modified type-F infiltrometer.

Information of this type is expected to provide leads from which proper vegetation and ground surface treatments will eventually evolve to hold potential runoff upon the watershed and to lessen flood volumes and peak flows downstream.

PUBLICATIONS

(All publications in 1960 unless otherwise noted.)

ANONYMOUS. Montana laboratory develops new equipment. The Timberman 61(10): 73, illus. (No reprints available)

Describes new forest fire meteorological equipment developed by Northern Forest Fire Laboratory.

ANONYMOUS. Forest Service opens Northern Forest Fire Laboratory. The Timberman 61(11): 12, illus. (No reprints available)

Describes the facilities and the dedication of the new Northern Forest Fire Laboratory.

ANONYMOUS. Northern Idaho Forest Genetics Center. Brochure, 4 pp., illus.

Describes the genetics center and the research and seed orchard technology now under way. Briefly summarizes plans for future research.

BAILEY, REED W., and OTIS L. COPELAND, Jr. Low flow discharges and plant cover relations on two mountain watersheds in Utah. I. A. S. H. Comm. Surface Waters 51: 267-278, illus.

Summarizes 22 years of streamflow records as a basis for comparing behavior of low flow discharges from two adjacent mountain watersheds in northern Utah that have a history of contrasted use.

BARROWS, J. S. Control of lightning fires in American forests. World Forestry Congr. Proc., 13 pp.

Reviews the magnitude and character of lightning fire control problems in American forests. Summarizes progress of Project Skyfire lightning research program and the general methods of lightning fire control.

BARROWS, J. S. Forest fire research at the Northern Forest Fire Laboratory. Canad. Pulp and Paper Assoc., Woodlands Section Ann. Meeting, Release No. 13, 8 pp., illus.

Describes facilities and outlines the research program of the Northern Forest Fire Laboratory. Summarizes current research results and high priority problems for future study.

BARROWS, J. S. Forest fire research during the next 50 years of western forestry. West. Forestry and Conserv. Assoc., West. Forest Fire Res. Coun. Proc., pp. 5-8.

Summarizes the challenge of research to meet national needs in protecting the forest resource for an increasing population. Outlines specific goals and possibilities for basic studies.

BAUGHMAN, R. G., and D. M. FUQUAY. Characteristics of Rocky Mountain lightning storms. West. Forestry and Conserv. Assoc., West. Forest Fire Res. Coun. Proc., pp. 9-12, illus. (No reprints available)

Describes occurrence, duration, and characteristics of lightning storms over the period 1955-1958 in the northern Rockies.

BINGHAM, R. T. (Ed.) An annotated directory to Canadian and foreign workers in forest genetics and related fields. Jour. Forestry 58: 602-618.

A cross-referenced directory giving names, addresses, and subject matter specialties of 744 Canadian and foreign workers in forest genetics.

BINGHAM, R. T. Progress in breeding blister rust resistant western white pine. Seventh West. Internatl. Forest Disease Work Conf. Proc., pp. 54-57. (No reprints available)

Summarizes results to date of first generation breeding work and what these results mean in respect to production of resistant western white pine planting stock in the near future.

BINGHAM, R. T., A. E. SQUILLACE, and (J.W.WRIGHT)*. Breeding blister rust resistant western white pine. II. First results of progeny tests including preliminary estimates of heritability and rate of improvement. Silvae Genetica 9, Heft 2, 33-41, illus.

Describes and quantifies inheritance of blister rust resistance in controlled pollinated progenies of western white pine, extending the analyses to prediction of per-generation gain in resistance.

BOYD, RAYMOND J., Jr. Deception Creek Experimental Forest. Brochure, 6 pp., illus.

This leaflet includes descriptions of research projects, management demonstrations, and a map showing the road system and study areas.

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*Parentheses indicate authors who are not members of Intermountain Station staff.

CAHILL, DONN B. The relationship of diameter to height of attack in lodgepole pine infested by mountain pine beetle. Res~~earch~~ Note 78, 4 ~~p~~p., illus. (Processed) U.S. Forest Serv. Intermountain Forest & Range Exp. Sta.

Shows how diameter measurements of lodgepole pine infested by mountain pine beetle can be used to estimate probable height of infestation on boles. Can be used to determine extent of felling required in a stand to insure proper chemical treatment to destroy brood.

CALLAHAM, R. Z. Selecting the proper seed source of ponderosa pine. Soc. Amer. Foresters Proc. 1959, ~~p~~p. 26-27.

Supplies factual evidence to support long-standing recommendations on guides for selecting proper seed sources. For best performance, seed should be collected within an elevational zone of 1,000 feet above or below the planting site, within 50 miles, and from average or better trees.

CALLAHAM, ROBERT Z. Experimental taxonomy—more than seed source studies. Ninth Internatl. Bot. Cong. Proc. II: 57 (Abstract) 1959. (No reprints available)

Stresses need for new methods of experimental taxonomy to gain an understanding of physiology, biochemistry, genetics, and comparative cytology and morphology in foresters' investigations of variation. New approaches, such as used in ponderosa pine studies, can lead quickly and efficiently to resolving patterns of variation.

CALLAHAM, ROBERT Z. Temperature and seed germination for races of ponderosa pine. Ninth Internatl. Bot. Cong. Proc. II: 57-58(Abstract) 1959. (No reprints available)

Rates of germination were determined at 8°, 16°, 24°, and 36° for half-sib progenies from 20 sources. Significant regional and local differences in germinative energy and germinative capacity were detected at most temperatures.

COLE, WALTER E. Sequential sampling in spruce budworm control projects. Forest Sci. 6: 51-59, illus.

Presents a sequential plan for sampling independently either or both prespray and postspray budworm larval populations and permits classification of these populations within specific limits of accuracy, based on the actual number of larvae per sampling unit, a 15-inch twig. Only postcontrol sampling is required to determine success of aerial spray projects.

(COLSON, DeVER). Forecasting thunderstorms in the northern Rocky Mountains from 5-day mean charts. West. Forestry and Conserv. Assoc., West. Forest Fire Res. Coun. Proc., pp. 18-20, illus. (No reprints available)

Describes a method for forecasting lightning storms according to 5-day meteorological charts of 700 mb observations. Explains results of this method as a means of extending lightning forecasts beyond 24- to 48-hour periods.

COPELAND, OTIS L., Jr. Watershed restoration. Jour. Soil and Water Conserv. 15: 105-120, illus.

A photo record of conservation practices applied in the Wasatch Mountains of Utah to restore flood control on damaged watersheds.

CRADDOCK, GEORGE W. Floods controlled on Davis County Watersheds. Jour. Forestry 58: 291-293, illus.

Sketches the flood history, the determination of the causes of the floods, and the development, application, and testing of flood control measures.

CRADDOCK, GEORGE W., and REED W. BAILEY. Progress in watershed management. American Forestry: six decades of growth. Washington, D. C.: Society of American Foresters. pp. 137-147.

Sketches professional growth of watershed management from its beginnings in the late 1800's to the present. Discusses present status of watershed protection, watershed rehabilitation, and water yield improvement, and suggests directions for future coordinated action.

(CROFT, A. RUSSELL), and LINCOLN ELLISON. Watershed and range conditions on Big Game Ridge and vicinity, Teton National Forest, Wyoming. U. S. Forest Serv., 37+ pp., illus. (Processed)

Reports an inspection of the Jackson Hole elk summer range in the Teton wilderness area. Drastic deterioration of vegetation and soil on high mountain herblands grazed intensively by elk are described and illustrated. Livestock have never used this range. Excessive numbers of elk are the chief cause of plant and soil deterioration.

DIVISION OF FOREST FIRE RESEARCH. The Northern Forest Fire Laboratory. Brochure, 12 pp., illus.

Describes the facilities and research program at the Northern Forest Fire Laboratory. Presents targets for forest fire research and the role of fire sciences in solving these problems.

DIVISION OF FOREST INSECT RESEARCH. Forest insect conditions in the Intermountain and Northern Rocky Mountain States during 1959. Misc. Pub. 23, 12 pp., illus. (Processed)

Reviews the status of numerous forest insect pests during 1959, including those of major and minor economic importance.

ELLISON, LINCOLN. Influence of grazing on plant succession of rangelands. Bot. Rev. 26: 1-78. (Out of print)

Reviews the effects of grazing on major vegetation types throughout the United States, the effects of herbage removal on the individual plants, and the ecological relations of grazing to the range.

FAHNESTOCK, GEORGE R. Logging slash flammability. Research Paper 58, 70 pp., illus. (Processed)

Reports the results of logging slash flammability research on nine western tree species. Explains variations in flammability according to species, amount, and age of logging slash.

FUQUAY, DONALD M. Generator technology for cloud seeding. Jour. Irrigation and Drainage Division. Amer. Soc. Civil Engr. Proc. 86 (IR 1): 79-91, illus. (No reprints available)

Reviews the state of technology of equipment for cloud seeding. Presents methodology and results of calibrating generators. Describes details of a new type airborne silver iodide smoke generator.

FUQUAY, DONALD M. A mobile atmospheric research laboratory. Modern Precision, Leeds & Northrup Co., 20(2): 4. (No reprints available)

Describes a mobile laboratory used to collect valuable weather data in the field.

GRAHAM, DONALD P. Dwarfmistletoe survey in Kaniksu National Forest. Re~~search~~ Note 74, 6 ~~p~~p., illus. (Processed) U.S. forest Serv. Intermountain forest & Range Exp. Sta.

More than 50 percent of the roadside strip traversed in western larch stands showed dwarfmistletoe infection. Larch dwarfmistletoe was more prevalent in sawtimber stands than in immature stands. Lodgepole pine and Douglas-fir dwarfmistletoes are a problem in some areas.

GRAHAM, DONALD P. Dwarfmistletoe survey in Nezperce National Forest. Re~~search~~ Note 75, 7 ~~p~~p., illus. (Processed) U.S forest Serv. Intermountain forest & Range Exp. sta.

Roadside survey showed that infected Douglas-fir, western larch, or lodgepole pine occurred in 54 percent of the forest and in 79 percent of the volume on 200 plots established in infected stands.

GRAHAM, DONALD P. Surveys expose dwarfmistletoe problem in Inland Empire. West. Conserv. Jour. 17(1): 56-58, illus. (No reprints available)

Presents the general distribution of dwarfmistletoe in northeastern Washington, northern Idaho, and western Montana and some information on damage caused.

HARDY, CHARLES E., and ARTHUR P. BRACKEBUSCH. The Intermountain fire-danger rating system. Soc. Amer. Foresters Proc. 1959, pp. 133-137, illus.

Reviews the history of fire-danger rating and the development and use of the Intermountain system. Explains application of fire-danger rating in evaluating cumulative and current weather effects.

HAUPT, HAROLD F. Variation in areal disturbance produced by harvesting methods in ponderosa pine. Jour. Forest~~ry~~ 58: 634-639, illus.

Discusses the baring of soil by harvesting timber on 16 compartments of the Boise Basin Experimental Forest as related to the number and volume of trees removed.

KIDD, W. J., Jr. The advantages of using ethylene glycol in seasonal storage precipitation gages and a method for computing the initial charge. Jour. Forestry 58: 882-884, illus.

The method for determining the quantity of ethylene glycol required for the initial charge is based on the monthly minimum expected temperatures, the accumulated precipitation expected, and the freezing point curve for its aqueous solutions.

KIMMEY, JAMES W. Cull factors for heart rots and their use in marking guides. Seventh West. Internatl. Forest Disease Work Conf. Proc., pp. 67-72. (No reprints available)

A discussion defining cull factors, their purpose and use, and methods of application. Reviews cull factors determined for forest stands of western United States, and need for others. Explains use of cull factors in preparing marking guides.

KIMMEY, JAMES W., and DONALD P. GRAHAM. Dwarfmistletoes of the Intermountain and Northern Rocky Mountain Regions and suggestions for control. Res~~earch~~ Pap~~er~~ 60, 20+ pp., illus. (Processed) U. S. forest serv. Intermountain forest & Range Exp. Sta.

Assembles and summarizes pertinent published information and presents other information that may be useful in planning control of the principal dwarfmistletoes in these regions.

KOTOK, E. S. Industries in Mountain States will accent more fiber use. West. Conserv. Jour. 17 (1):29. (No reprints available).

Growth of the timber-using industries in the Rockies during the coming decade will generally follow national growth patterns, with probably greater than average increases in fiber-using industries such as paper and particle boards. Timbermen, to meet growing competition from substitute products, will have to find cheaper ways to harvest, produce a greatly improved product, and gain a more intelligent technical understanding of the products they sell.

LEAPHART, CHARLES D. A root stain disease of eastern white pine. Plant Disease Rptr. 44: 704-706, illus. (Processed)

Reports rapid killing of eastern white pine in two 50-year-old plantations by a root stain fungus *Verticicladiella* sp. in northern Montana. No killing of associated native trees has been found.

LLOYD, MERLE G. Microclimate studies. Results to date and their practical application to control problems in Region 1. Natl. Blister Rust Control Meeting 1959 Proc. 29: 36. (No reprints available)

Study results will enable forest managers to delineate high and low rust-hazard areas regardless of ribes populations. Standards for ribes tolerance and for width of protective zones can be established.

LLOYD, MERLE G. Microclimate phases of blister rust control. Seventh West. Internatl. Forest Disease Work Conf. Proc., pp. 59-64. (No reprints available)

Studies of microclimate are designed to answer questions of forest managers who have encountered numerous trouble areas in control of white pine blister rust in the Inland Empire and elsewhere.

MEEUWIG, RICHARD O. Watersheds A and B—a study of surface runoff and erosion in the subalpine zone of central Utah. Jour. Forestry 58: 556-560, illus.

Discusses the overland flow and erosion characteristics of watersheds A and B during the time from 1912 through 1958 as divided into periods by watershed conditions.

(MILLER, ROBERT L.), and ALVIN K. WILSON. Sawlog production in Colorado and Wyoming, 1957. Rocky Mountain Forest and Range Expt. Sta. Forest Survey Release 3, 6 pp., illus. (Processed)

Sawmills in Colorado received 206,434,000 board feet of sawlogs (International ¼-inch log rule volume) and Wyoming sawmills received 109,188,000 board feet of logs in 1957, according to an official survey. This report analyzes sawmill log receipts by timber species and geographic origin.

MOESSNER, KARL E. Aerial volume tables for ponderosa pine type in the Rocky Mountains. Res~~earch~~ Note 76, 6 pp. (Processed) U.S. forest Serv. Intermountain forest & Range-

Describes method of preparing tables, lists standard measures of accuracy and two tests, and includes cubic-foot, International ¼-inch, board-foot, and Scribner board-foot volume tables. -Exp. Sta

MOESSNER, KARL E. Estimating the area in logging roads by dot sampling on aerial photos. Research Note 77, 4 pp., illus. (Processed)

Describes technique, evaluates accuracy, and shows cost compared to cost of usual methods of determining area disturbed during logging.

MOESSNER, KARL E. Estimating timber volume by direct photogrammetric methods. Soc. Amer. Foresters Proc. 1959, pp. 148-151.

Discusses a method of estimating timber volume by means of sample plots measured on aerial photos. The study compares over-all volumes and costs with 100-percent ground cruises, and indicates accuracies equal to those obtained by ground cruising.

MOESSNER, KARL E. Photo interpretation in forestry. *Quantitative characteristics.* Washington, D. C. American Society of Photogrammetry. Manual of Photo Interpretation. Chap. 7 pp. 459-469, illus.

MOESSNER, KARL E. Training handbook: basic techniques in forest photo interpretation. 73 pp., illus. (Processed)

Outlines training techniques and describes a 13-problem course, including accepted solutions.

MOESSNER, KARL E. Training kit: basic techniques in forest photo interpretation. (Processed)

Includes 13 exercises, necessary aerial photos, photo interpretation aids, and tables used in solving the exercises. (Available only from Regional Forester, U. S. Forest Service, Ogden, Utah, at $10 each.)

MORRIS, MEREDITH J. An abstract bibliography of statistical methods in range and related pasture research. Part I. The measurement of vegetation. Part II. Use of animals in measuring herbage production. Part III. Statistical theory and methods. 300 pp. (Processed) (Not available for distribution)

PACKER, PAUL E. Some terrain and forest effects on maximum snow accumulation in a western white pine forest. 28th Ann. West. Snow Conf. Proc., pp. 63-66.

Presents results of a study to determine the variability of maximum snow water content at different elevations, on various aspects, and under forest canopy conditions reflecting different forest management treatments. Snow accumulation data in natural and clear-cut forest openings and in forest stands of various densities in the Priest River Experimental Forest in northern Idaho were available for study.

PLUMMER, A. PERRY, and (HOMER D. STAPLEY). Research in game forage restoration in Utah. West. Assoc. State Game and Fish Commrs. Proc. 1959, pp. 159-166. (No reprints available)

Describes objectives, methods, and results of game winter range restoration in Utah. A balance of shrubs, grasses, and broad-leaved herbs is most suitable for establishing and maintaining winter range production. Direct seeding, as well as transplanting nursery stock, seedlings, and wildings, is important in improving game range.

(SHAW, CHARLES GARDNER), and CHARLES D. LEAPHART. Two serious foliage diseases of western white pine in the Inland Empire. Plant Disease Rptr. 44: 655-659, illus. (Processed)

Reports and describes a needle-cast disease caused by the fungus *Hypodermella arcuata* in the upper crowns, and a blight of the needles in the lower crown caused by *Lecanosticta* sp. These two fungi caused widespread damage by crown deterioration and tree mortality in western white pine.

SHEARER, RAYMOND C. Western larch seed dispersal over clear-cut blocks in northwestern Montana. Montana Acad. Sci. Proc. 19: 130-134.

Dissemination of western larch seed over a 15-, a 30-, and a 60-acre clear-cut block is discussed. Most seed was dispersed uphill during the 6-year study period. Enough seed was dispersed to all parts of the largest block during good seed years to establish satisfactory stocking on bare soil.

SHEARER, RAYMOND C., and DAVID TACKLE. Effect of hydrogen peroxide on germination in three western conifers. Research Note 80, 4 pp., illus. (Out of print)

Germination of western larch and Douglas-fir seed was hastened in simple petri dish tests by moistening with a 3-percent solution of hydrogen peroxide instead of water. However, germination of subalpine fir seed was not significantly stimulated by this treatment.

(SMART, WILLIAM W. G., Jr., GENNARD MATRONE), WELDON O. SHEPHERD, and others. The study of the comparative composition and digestibility of cane forage (*Arundinaria* sp.) North Carolina Agr. Expt. Sta. Tech. Bul. 140, 8 pp.

Three indicator methods (lignin, silica, and copper-chlorophyll) of evaluating composition and digestibility showed different amounts of digestible nutrients, but showed similar effects of burning, shade, and season. Forage on burned range was most nutritious. Shade tended to reduce digestible carbohydrate fractions, but to increase digestible protein in fall and winter.

STAGE, ALBERT R. Computing growth from increment cores with point sampling. Jour. Forestry 58: 531-533.

Describes procedure of selecting trees for increment sampling with an angle-gauge, discusses advantages of the system, and presents formulae for computing the ratio of increment to basal area and for estimating the fraction of trees to be bored at each plot.

TACKLE, DAVID, and RAYMOND C. SHEARER. Strip-thinning by bulldozer in a young lodgepole pine stand. Montana Acad. Sci. Proc. 19: 142-148. (No reprints available)

Assesses equipment and operator effectiveness, and compares relative growth in diameter, basal area, and height of trees in reserve strips of varying width.

TERRELL, TOM T., and ROBERT E. DENTON. Insect attacks look less dangerous for '60. West. Conserv. Jour. 17(1): 30-31, 45-46, illus. (No reprints available)

Reviews general forest insect infestations during 1959 in Montana and northern Idaho.

(WATERS, CHARLES W.*) Significance of life history studies of *Elytroderma deformans*. Seventh West. Internatl. Forest Disease Work Conf. Proc., pp. 98-102. (No reprints available)

Definitely establishes the presence of the fungus hyphae in phloem cells of host twigs, and their growth into the axes of the terminal buds and the developing needles contained therein. The systemic nature of infection was previously a theory based on conjecture.

WATT, RICHARD F. Second-growth western white pine stands: site index and species changes; normality percentage trends; mortality. U. S. Dept. Agr. Tech. Bul. 1226, 60+ pp., illus.

Analyzes long-time records from 94 permanent sample plots in second-growth western white pine stands from 20 to 100 years old. Present site index curves proved reliable. Composition was shown to be established by the time stands are 30 years old. Presents alinement charts for determining changes in stand density. Mortality caused loss of 30 percent of basal area, 22 percent of cubic-foot volume, and 10 percent of board-foot volume between stand ages of 30 and 100 years.

WELLNER, CHARLES A. What research do we most need and how can we get it? 50th West. Forestry Conf. West. Forestry and Conserv. Assoc. Proc. 1959, pp. 45-48. (No reprints available)

Discusses the urgent need for increasing research effort in all branches of forestry.

WELLNER, CHARLES A. Devices to measure spiral grain and twisting in poles. Jour. Forestry 58: 117-118.

Describes a device called a "bolaxis" used to determine slope of surface grain of trees and poles, and another device used for measuring angular twisting in place of upright test poles.

WELLNER, CHARLES A., and RAYMOND J. BOYD. Partial cuttings in mature stands of the western white pine type. Soc. Amer. Foresters Proc. 1959, pp. 27-32, illus.

Summarizes studies conducted since 1941 of growth and mortality of 5,704 tagged trees on 16 sample plots. Gross growth, mortality, net growth, and diameter growth were strongly associated with tree vigor.

WILSON, ALVIN K. An upswing in Montana's Christmas tree exports. Research Note 73, 4 pp., illus. (Processed)

Montana Christmas tree exports recovered from the decline experienced in 1957 and 1958 to achieve the second highest volume on record, nearly 3.8 million trees. This upswing is attributed to business recovery from the general recession of 1957-58 and to lessened insect defoliation on Douglas-fir, the principal Christmas tree species.

WILSON, ALVIN K. Northern Rocky Mountain pole production increased in 1959. Research Note 79, 4 pp. (Processed)

Commercial production totaled 428,581 poles in the northern Rocky Mountain area in 1959, an output 26 percent higher than that of 1958. This increased production rate reflects recovery of all forest industries from the general business recession of 1957-58.

WILSON, ALVIN K. Brief look at the pulpwood situation in Idaho and Montana. Pulp and Paper 34(11): 122. (No reprints available)

Although pulpwood cut in Idaho and Montana increased 325 percent between 1948 and 1956, the development of pulpwood potentialities in these States has barely started. Possibilities for pulpwood production are briefly considered here from the aspects of timber volume available, species suitability, and the use of sawmill residues.

(WRIGHT, J. W.), R. T. BINGHAM, and (K. W. DORMAN). Genetic variation within geographic ecotypes of forest trees and its role in tree improvement. Jour. Forestry 56: 803-809. (No reprints available)

A review of published works on intraspecific and interracial variation in forest tree species and a discussion of the possibility for utilizing this variation in forest tree improvement.

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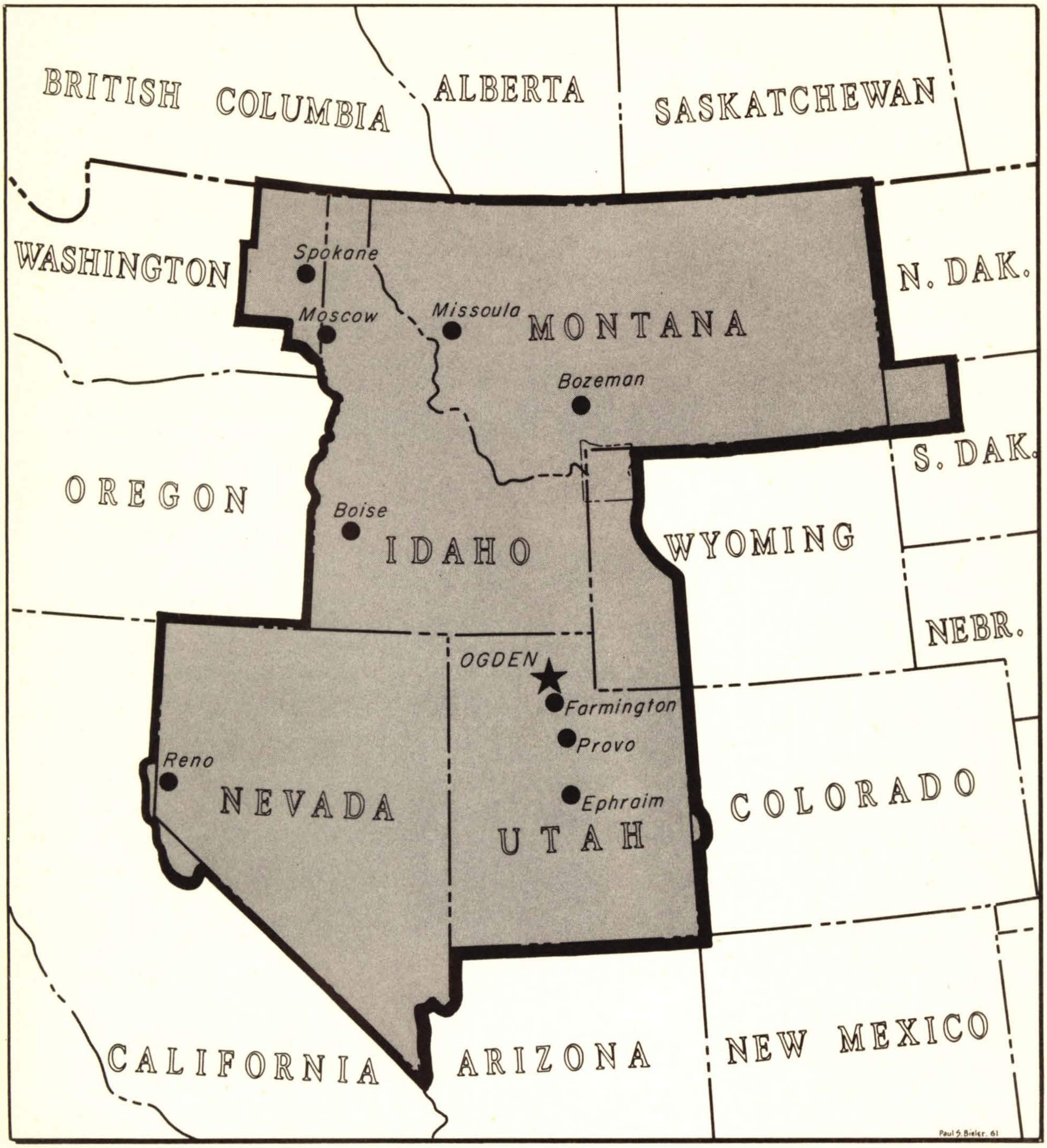
*Cooperator.

DPS, Utah General Depot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